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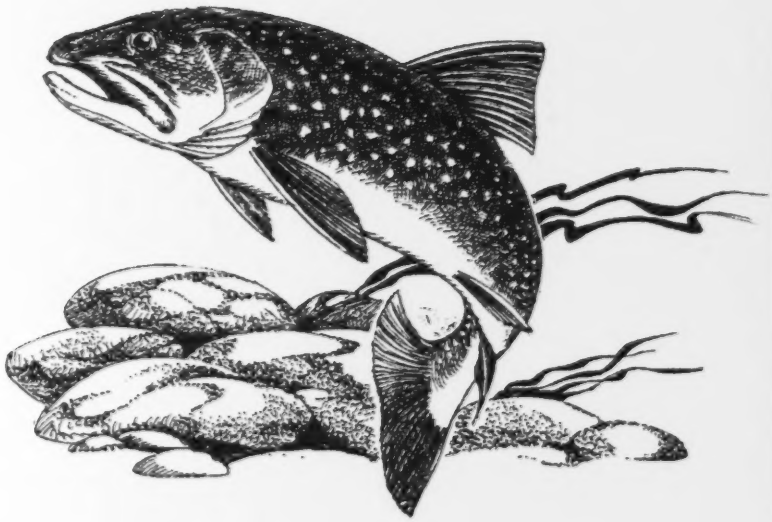
Status of the Bull Trout (*Salvelinus confluentus*) in Alberta

John R. Post
and
Fiona D. Johnston



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Alberta Conservation Association

Alberta
SUSTAINABLE RESOURCE DEVELOPMENT

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PREFACE

Every five years, the Fish and Wildlife Division of Alberta Sustainable Resource Development reviews the status of wildlife species in Alberta. These overviews, which have been conducted in 1991, 1996 and 2000, assign individual species "ranks" that reflect the perceived level of risk to populations that occur in the province. Such designations are determined from extensive consultations with professional and amateur biologists, and from a variety of readily available sources of population data. A primary objective of these reviews is to identify species that may be considered for more detailed status determinations.

The Alberta Wildlife Status Report Series is an extension of the general statusing exercises (1996 *Status of Alberta Wildlife, The General Status of Alberta Wild Species* 2000), and provides comprehensive current summaries of the biological status of selected wildlife species in Alberta. Priority is given to species that are potentially at risk in the province ("At Risk," "May Be At Risk"), that are of uncertain status ("Undetermined"), or which are considered to be at risk at a national level by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Reports in this series are published and distributed by the Alberta Conservation Association and the Fish and Wildlife Division of Alberta Sustainable Resource Development. They are intended to provide detailed and up-to-date information which will be useful to resource professionals for managing populations of species and their habitats in the province. The reports are also designed to provide current information which will assist the Alberta Endangered Species Conservation Committee to identify species that may be formally designated as "Endangered" or "Threatened" under Alberta's *Wildlife Act*. To achieve these goals, the reports have been authored and/or reviewed by individuals with unique local expertise in the biology and management of each species.

EXECUTIVE SUMMARY

Bull trout (*Salvelinus confluentus*) are a char species native to western North America, which colonized the major drainages of the eastern slopes of Alberta after the last glaciation. Since the early 1900s, this species has declined in both distribution and abundance, and is now ranked as "Sensitive" in Alberta, and "Threatened" under the Endangered Species Act throughout its range in the United States (lower 48 states). These declines have been attributed to the impacts of human activities. Human activities that limit bull trout abundance include migratory barriers, habitat degradation and fragmentation, angling pressure and past population management practices, and the stocking of non-native fish species. However, to more clearly understand the factors leading to the decline of this species in Alberta, the complex biology and habitat requirements of bull trout must be understood.

Bull trout express three main types of life history strategies; stream-resident populations reside within the tributaries in which they were reared; fluvial populations spawn in tributaries but reside in mainstem rivers; and adfluvial populations spawn in tributary streams but reside in lakes or reservoirs. As a result, bull trout have complex habitat requirements, and in some cases very large home ranges. The migratory patterns of bull trout, their spawning strategies, and their fidelity to spawning areas all have important management implications. Additionally, to maintain the genetic integrity of populations through genetic exchange from distinct populations, the development of regional rather than localized management plans is required. However, at present, all the information required to produce such a plan is not available. Further population surveys and long-term population monitoring are required to determine the status of bull trout populations within Alberta. A clearer understanding of the habitat requirements and population dynamics at all stages of the growth and life history strategies are required to determine the potential impacts that human activity may have on these populations. Finally, more information is needed on the direct and indirect impacts of human activity on these populations.

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INTRODUCTION

Bull trout (*Salvelinus confluentus*) are a char species that is native to western North America. This cold water species is thought to have been isolated in a number of glacial refugia in the Pleistocene and recolonized after the last glacial period (Nelson and Paetz 1992, Bellerud et al. 1997, Haas and McPhail 2001, Thomas et al. 2001). In Alberta, they are the only native char to historically occupy all the drainages of the eastern slopes, and in the North Saskatchewan and Red Deer River drainages they are the only native, stream-dwelling char species (Nelson and Paetz 1992, Berry 1994). Bull trout display non-migratory and migratory (adfluvial, fluvial, and anadromous) (see glossary, Appendix 1) life history strategies that have allowed them to distribute themselves widely.

Despite being widely distributed in this region, bull trout are no longer abundant, and populations have been declining for the last century (Rieman et al. 1997, Montana Bull Trout Restoration Team (MBTRT) 2000). This decline is generally attributed to human impacts on fish populations and their habitat. Past management practices that included bull trout eradication contributed to this decline (Colpitts 1997). During the 1920s, bull trout had a reputation as piscivorous, "junk fish", which were culled in an attempt to encourage "nobler species", such as the introduced rainbow, brook, and brown trout (Colpitts 1997). In November 1999, bull trout were recognized as a "Threatened" species throughout their range in the United States (lower 48 states), under the Endangered Species Act (MBTRT 2000, Haas 2001, Lohr et al. 2001, U.S. Fish and Wildlife 2001), and are currently ranked "Sensitive"* in Alberta (Alberta Sustainable Resource Development 2001a,b).

This report summarizes current information available on bull trout in Alberta, and is an important step in updating its status in the province.

HABITAT

Bull trout are found predominantly in the cool, high elevation, low to mid-order watersheds of western North America (Nelson and Paetz 1992, Rieman et al. 1997), and in lowland valleys and streams (Watson and Hillman 1997). They tend to select well-connected, structurally diverse streams that offer protection against high or low flow levels, the disruption of the stream bed, high water temperatures, freezing, and the loss of pools and cover (Cross and Everest 1997). This involves streams with stable channels and flows, low proportions of fine sediment, available cover, suitable water temperatures, and open migratory corridors (McCart 1997, Watson and Hillman 1997, Haas 2001). Watershed size and stream width appear to be important factors because they provide a connection between populations as sources of recolonization in the event of local extinction (Rieman and McIntyre 1995, Rieman and McIntyre 1996, Dunham and Rieman 1999). Habitat diversity and connectivity allow for the expression of all types of life history strategies, and the persistence of the species (Rieman and Clayton 1997).

Water temperature and groundwater input are critical habitat characteristics that limit the migration, spawning, and incubation periods of bull trout. Geographically, temperature limits the southern and eastern boundaries of bull trout distribution (Buchanan and Gregory 1997, MBTRT 2000). Bull trout are generally found in mountain streams with maximum water temperatures <18°C (Berry 1994, Adams and Bjornn 1997). Optimal habitat appears to be ≤15°C, with the highest densities occurring

* See Appendix 2 for definitions of selected status designations

at temperatures of ≤12-13°C (Buchanan and Gregory 1997, McCart 1997, MBTSG 1998, Haas 2001).

1. Spawning and Rearing. - Bull trout spawn in coarse substrates of gravel to cobble where there is a low level of fine sediment and high substrate permeability to aerate their eggs (Berry 1994, MBTRT 2000). Preferred spawning substrate is gravel-cobble (16-64 mm diameter) with <10% fine sediment (<1.0 mm) (McPhail and Murray 1979, James and Sexauer 1997). Larger fish utilize larger substrates towards the center of the channel because they are better able to move this material, and it is presumably where there is a lesser chance of the stream drying up during low flows (Berry 1994, MBTSG 1998, Mushens and Post 2000). This may result in relative differences in survival rates between different life history strategies, as migrants tend to be bigger than resident bull trout, and could have important management implications to any activities that may decrease winter flow levels.

Successful incubation requires appropriate gravel composition, permeability, water temperature and surface flow conditions. In general, the level of fine sediment should not exceed 35-40% (< 6.35 mm) during incubation (MBTSG 1998); however, Fairless et al. (1994), found that survival was not related to the proportion of fine sediment < 6.35 mm.

The young-of-year (YOY) bull trout over-winter in the interstitial sub-surface flow, even under no visible surface water, within and upstream of the spawning area (Boag and Hvenegaard 1997). The YOY emerge in the spring seeking stream margins with heterogeneous structure, low velocity backwaters, and side channels (McPhail and Murray 1979, Cross and Everest 1997, MBTSG 1998).

Juvenile bull trout exhibit a strong preference for low water velocity (Earle and McKenzie 2001). As they grow, bull trout seek out deeper water pools often associated with large woody debris in lower tributary reaches (McPhail and Murray 1979, Ratcliff et al. 1996, Connor et al. 1997, Cross and Everest 1997, MBTSG 1998, Earle and McKenzie 2001). Avoidance of predation and competition greatly influences their distribution (Goetz 1997a, Sexauer and James 1997, Earle and McKenzie 2001). Cover provided by boulders found in runs and riffles with pools downstream is a preferred habitat for protection as well as for feeding. These areas provide easy access to higher velocity waters with abundant food supplies, but still provide velocity breaks that require lower energy expenditure to maintain position (Baxter and McPhail 1997, Connor et al. 1997, MBTRT 2000, Earle and McKenzie 2001). Shade levels, undercut banks, large woody debris volume and pieces, substrate composition in riffles, and bank stability are all good predictors of juvenile bull trout presence (Dambacher and Jones 1997).

Juvenile bull trout seek concealment during the day in the low velocity areas under cobbles, and at night they move out further from cover to feed in runs, channel margins and backwater areas of riffles (Baxter and McPhail 1997, Goetz 1997a, Sexauer and James 1997, Thurow 1997). Juvenile bull trout also utilize different habitats seasonally. Although juvenile bull trout select low velocity areas in all seasons, the selection of water depth and substrate varies between seasons (Sexauer and James 1997). Overhead cover, deep stable water, low velocities, and lack of anchor ice appear to be important winter habitat criteria (Thurow 1997). These diel (see glossary, Appendix 1) and seasonal differences in habitat use have important implications to fisheries surveys, as they may affect sampling locations and the effectiveness of various techniques used to

determine the distribution and abundance of bull trout.

2. Adults. - The habitat utilized by adult bull trout, similar to that of juveniles, is related to selection of low velocity areas that provide the appropriate temperature, protective cover, and an ice-free refuge in the winter.

During the summer, fluvial adults are strongly associated with pools (Clayton 1999). Bull trout may seek out groundwater as it provides a thermal refuge in both the summer and winter (Goetz 1997b, Buchanan and Gregory 1997, MBTSG 1998). They appear to return to the same over-wintering habitat with high fidelity once they have completed their spawning migrations (Berry 1994, McLeod and Clayton 1997, MBTSG 1998). Overhead or instream cover appears to be another important component of over-wintering habitat (Rhude and Rhem 1995).

Adfluvial populations use profundal, littoral and pelagic sections of the lake (see glossary, Appendix 1). However, they are more abundant in the deeper sections of the lake where water temperatures are lower (Connor et al. 1997, MBTSG 1998, MBTRT 2000, Mushens and Post 2000). Adult bull trout tend to use the pelagic area more often in the spring and fall, and use the littoral zone for foraging excursions (MBTSG 1998). Adfluvial bull trout mostly rest on the bottom during the day and then activity peaks at night, especially on moonless nights (Connor et al. 1997). As with juvenile bull trout, consideration of this variable habitat use is important in selecting sampling locations and techniques.

CONSERVATION BIOLOGY

1. Identification. - Bull trout, (*Salvelinus confluentus*) are a char species native to Alberta and western North America, and are a member of the family, Salmonidae. Bull trout were first described as a distinct species from dolly varden (*Salvelinus malma*) in 1978 (Cavendar 1978) and this was morphologically confirmed in 1991(Haas and McPhail 1991).

Bull trout are long slender fish with a comparatively large head and jaws from which the name "bull" originated. They are olive-green to blue-grey in appearance, although lake dwelling fish may have silvery sides (Nelson and Paetz 1992, Berry 1994). They have pale, yellow-orange round spots along their sides and backs. This distinguishes them from true trout species (i.e. rainbow (*Oncorhynchus mykiss*), cutthroat (*Oncorhynchus clarki*), and brown trout (*Salmo trutta*), which have dark spots, and brook trout (*Salvelinus fontinalis*), which are also char species (Anonymous 1994). Bull trout are often identified by the absence of black spots on the dorsal fin which are present on other char and trout found in Alberta (Berry 1994). They usually have pale bellies, which may turn red or orange in spawning males (Nelson and Paetz 1992, Berry 1994). Their tail fin is only slightly forked, and pelvic or anal fins may have a white leading edge, but this is not followed by black as in brook trout (Nelson and Paetz 1992, Anonymous 1994).

Bull trout (*Salvelinus confluentus*) are distinguished from dolly varden (*Salvelinus malma*) both geographically and morphologically. In Alberta, the non-native dolly varden are only found in Chester Lake (Kananaskis River Drainage), where bull trout do not occur (Nelson and Paetz 1992). Dolly varden are mostly anadromous fish, and are commonly found in streams and lakes along the west coast of Canada and the northwestern United States (Nelson and Paetz 1992, Berry 1994). There are locations where these two species live in sympatry (see glossary, Appendix 1), however, they maintain two distinct gene pools despite genetic evidence

indicating that ancient introgression as well as the fact that recent production of viable hybrids has occurred. This suggests some sort form of reproductive isolation or natural selection exists between them (Haas and McPhail 1991, Baxter et al. 1997, Leary and Allendorf 1997, Hagen and Taylor 2001, Taylor et al. 2001).

Morphologically, bull trout are distinguished from dolly varden by a number of characteristics (Figure 1). In bull trout, the distance from the center of the eye to the top of the head is less than the distance from the center of the eye to the nostril. These distances are more equal in dolly varden. The head of the bull trout is broader in dorsal and anterior views as opposed to the more compressed appearance of the dolly varden head. Bull trout have stout gillrakers with strong teeth on the inner margin, whereas dolly varden have long gillrakers that lack teeth on the inner margin (Nelson and Paetz 1992). Morphometric identification protocol is discussed in Haas and McPhail (1991). Haas et al. (2001) found that the current misidentification rate is quite high even among fish biologists, with up to half of the bull trout being misidentified, while only a small proportion of dolly varden are misidentified.

2. Life History. - There are three main life history strategies expressed by bull trout: stream resident, fluvial, and adfluvial (see glossary, Appendix 1) (Berry 1994, Fitch 1997, James and Sexauer 1997, McCart 1997, Rieman and Clayton 1997, Rieman and Myers 1997, MBTRT 2000). Bull trout usually reach sexual maturity at about 5-7 years of age with

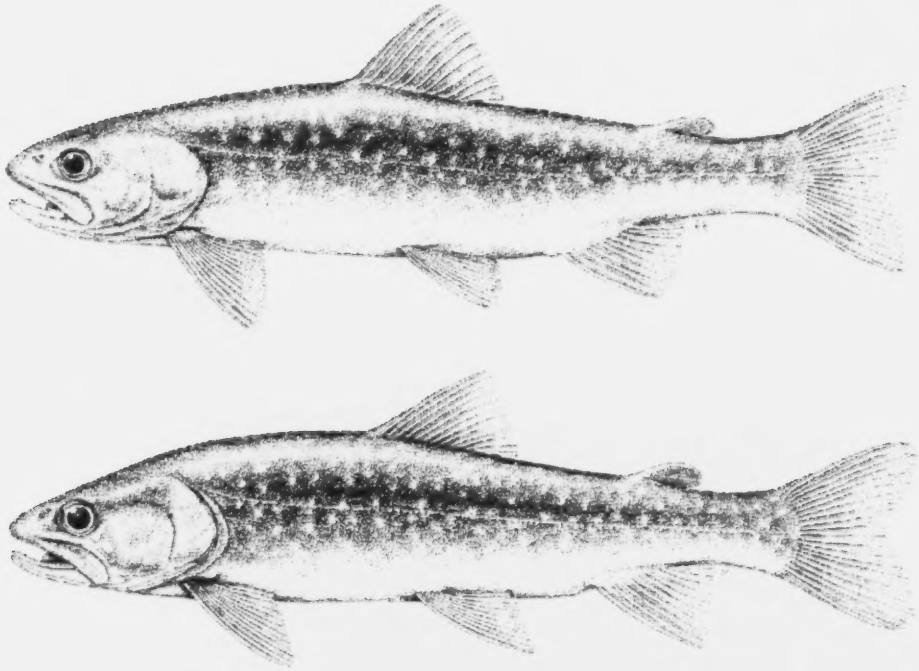

Figure 1. Composite drawings of dolly varden (top) and bull trout (bottom). Drawings were done by Karen Klitz. Extracted from Haas and McPhail (1991).

an extreme range of 3-8 years of age (Allan 1980, Berry 1994, Ratcliff et al. 1996, Rieman and McIntyre 1996, Connor et al. 1997, Herman 1997, McCart 1997, Mushens and Post 2000). In two fluvial populations, males were found to mature earlier than females (Allan 1980, McCart 1997). In contrast, Mushens and Post (2000) found that females matured first in an adfluvial population.

The body size of bull trout at maturity varies substantially among life history strategies. The average size at maturity for a resident population is 250 mm, with a range of 150-300 mm (Bellerud et al. 1997, Earle and McKenzie 2001). Migratory populations achieve greater sizes at maturity because they live as adults/sub-adults in more productive environments. The average length at maturity in a fluvial population is >400 mm (1050 g), ranging from 240-730 mm (Allan 1980, Brewin 1994b, Rhude and Rhem 1995, Clayton 1999, Hvenegaard and Thera 2001). The body size of adfluvial bull trout is generally larger than of fluvial bull trout. The average length in these populations is greater than 400 mm, with a range of 330-900+ mm (600-7200 g) (Ratcliff et al. 1996, Rieman and McIntyre 1996, Herman 1997, Rieman and Myers 1997, MBTSG 1998, Baxter and Westover 1999, Mushens and Post 2000).

Fecundity (see glossary, Appendix 1) is proportional to body size, with small resident females producing 500 eggs and large migratory females producing 2000-5000 eggs (McPhail and Murray 1979, Berry 1994). Egg size ranges from 4.8-6.2 mm diameter (McPhail and Murray 1979, Allan 1980). Quantitative relationships between body size and fecundity are available in Goetz (1989) and Mushens and Post (unpubl. data).

The timing and extent of spawning migrations varies substantially among populations of bull trout. Resident populations, by definition, typically migrate only short distances for spawning, rearing, and over-wintering habitat. In contrast, some populations of migratory adults must travel extensive distances (250 km) to their spawning grounds (Allan 1980, McLeod and Clayton 1997, MBTRT 2000, Burrows et al. 2001). Bull trout begin their migration between late-May and August, depending on the distances to be travelled (McPhail and Murray 1979, Allan 1980, Bellerud et al. 1997, McLeod and Clayton 1997, Clayton 1998, Hvenegaard and Fairless 1998, Olmsted et al. 1999, Westover 1999, Burrows et al. 2001, Hvenegaard and Thera 2001). Migratory movements generally occur at night (McPhail and Murray 1979, Ratcliff et al. 1996, MBTSG 1998, Mushens and Post 2000). Younger bull trout may enter the creek first, finish gamete development upstream, and spawn at the same time as older fish that entered the tributary at a later date but ready to spawn (McPhail and Murray 1979, Herman 1988, Herman 1997, Mushens and Post 2000).

Spawning occurs from mid-August to late-October (McPhail and Murray 1979, Allan 1980, Berry 1994, Brewin 1994b, Ratcliff et al. 1996, Rieman and McIntyre 1996, Bellerud et al. 1997, Rieman and Myers 1997, Hvenegaard and Fairless 1998, Westover 1999, MBTRT 2000, Mushens and Post 2000). In general, bull trout display a high fidelity to spawning areas, however, there is some evidence of switching, at least within localized areas (McPhail and Murray 1979). There is also strong evidence that bull trout may display alternate year spawning or resting periods between consecutive spawning events, with as little as 25% of the population repeat spawning (Rhude and Rhem 1995, Hvenegaard and Fairless 1998, Hvenegaard and Thera 2001). However, repeat spawning dominates in the majority of cases (Allan 1980, Ratcliff et al. 1996, Clayton 1998, Baxter and Westover

1999, Mushens and Post 2000). It is likely that in colder and less productive systems it takes more than one season to accumulate the energy necessary to produce gametes and migrate, leading to alternate year spawning. This has implications for population surveys done on an annual basis.

Bull trout eggs incubate in the gravel and hatch from March to April (Allan 1980, Berry 1994, Baxter and McPhail 1997, MBTRT 2000). The incubation period is temperature dependent, varying between 100-200 days (Allan 1980, Berry 1994). Eggs require temperatures less than 8°C to survive, and have an inter-gravel incubation optimum of 2-4°C (Berry 1994, Fairless et al. 1994, MBTSG 1998). High temperatures (> 8°C) and resulting low dissolved oxygen levels increase the rate of yolk absorption and decrease the size of fry. This suggests that bull trout have a cold water adaptation (McPhail and Murray 1979, Giles and Van der Zweep 1996). In addition to moderating the thermal regime, groundwater prevents the formation of frazil and anchor ice, which can scour or disturb the substrate, thereby compromising egg viability (Fairless et al. 1994, MBTSG 1998). Freezing may penetrate 15-20 cm into the substrate (Fairless et al. 1994), and may be avoided by deeper burial within redds (see glossary, Appendix 1). Low temperatures of the bull trout habitat may lead to lower growth rates when compared with other salmonids; however, lower temperatures do discourage the invasion of other species with higher temperature requirements and prevent competitive exclusion (MBTRT 2000).

At emergence, fry range in length from 21-33 mm (Allan 1980, Ratcliff et al. 1996, Reiser et al. 1997). Fry grow rapidly, and in a favourable environment, may gain 40 mm in their first summer (McPhail and Murray 1979). There appears to be a downstream migration of young-of-year shortly after emergence in the spring to lower velocity areas or lakes (McPhail and Murray 1979, Allan 1980, Bellerud et al. 1997, Connor et al. 1997, Reiser et al. 1997). Unfortunately, little is known about the movements of young-of-year and small juveniles, in part because they are too small to catch in traditional sampling gear.

The timing of migration of juveniles to rivers and lakes appears to be highly variable among systems. Fish range from one to four years old (60-300 mm in length) when they migrate to these environments (McPhail and Murray 1979, Brewin 1994a, Ratcliff et al. 1996, Baxter and McPhail 1997, Rieman and Myers 1997, Reiser et al. 1997, Sexauer and James 1997, Stelfox 1997, MBTRT 2000, Mushens and Post 2000). Often the migratory movement occurs in the fall (McPhail and Murray 1979, Bellerud et al. 1997, Reiser et al. 1997, Mushens and Post 2000). This timing may reduce the risk of predation from adults migrating upstream, and provide a chance to exploit higher quality food resources at lower risk while adults are involved in their spawning migration (Mushens and Post 2000). This information could be important to timing windows for development, as instream construction activities may limit juvenile recruitment to adult cohorts.

3. Growth and Feeding. - Life history strategies have important impacts on the growth rates of populations. Because of low productivity and low temperatures of rearing habitat, the growth rate for juveniles on an insect diet, is quite low (Berry 1994). Once juveniles reach 100-110 mm in length they may also eat small fish that may include sculpins, whitefish or salmon fry, or even cannibalistic consumption of bull trout (Goetz 1997a, MBTSG 1998). Their growth rate increases substantially when they enter rivers and lakes where prey fish are more abundant (MBTRT 2000; Mushens and Post 2000).

Prey availability is likely the reason resident bull trout populations are substantially smaller than migratory populations, and fluvial systems typically experience lower growth rates than adfluvial populations (Berry 1994, Ratcliff et al. 1996). For example, growth rates in the Kakwa River basin, Alberta, were estimated at 30 mm/yr for a fluvial population (Hvenegaard and Fairless 1998), whereas an adfluvial population in Lower Kananaskis Lake experiences a growth rate of 46 mm/yr (Stelfox 1997). Adfluvial populations are bottom-oriented, seeking cooler depths and making intermittent foraging trips into the littoral zone (Connor et al. 1997, MBTSG 1998). These fish are primarily piscivorous, although their diet may also include insect larvae and opossum shrimp (*Mysis relicta*) (Berry 1994, Connor et al. 1997, MBTSG 1998, Mushens and Post 2000). Smaller fish eat mostly benthos and amphipods from the littoral and pelagic areas, while larger fish specialize on fish (Connor et al. 1997, Mushens and Post 2000). Bull trout prey consists of whatever is available in the system (MBTSG 1998). Pinto Lake, Alberta, is a unique adfluvial population, because there are no fish species except bull trout in the system. Therefore, other than cannibalistic behaviour, these fish rely upon an invertebrate diet and as a result have a lower growth rate (10 mm/yr) (Herman 1997). Despite this, their growth rate is still higher than fluvial or resident populations in areas where fish prey are not abundant (Herman 1997). The large difference in growth rates among life history types and populations has important implications to bull trout management.

DISTRIBUTION

1. Alberta. - Bull trout colonized Alberta after the last glaciation approximately 13 000 years ago (Nelson and Paetz 1992). This species appears to have originated from two to four glacial refugia, which were located in the east, west, and north (Nelson and Paetz 1992, McCart 1997, Thomas et al. 2001). Genetic data suggest that descendents from several ancestral populations can be found in Alberta's drainages, and that these fish interbred while recolonization was occurring (Thomas et al. 2001). These populations have become more isolated resulting in the development of genetically distinct populations. Random amplified polymorphic DNA profiles indicate that populations in each Alberta drainage are distinct, (Peace, Athabasca, North Saskatchewan, St. Mary, and South Saskatchewan (Oldman and Bow)) as are populations within each drainage (Thomas et al. 2001). In the South Saskatchewan drainage, populations were found to be distinct in the Belly, Waterton, Castle and Carbondale rivers. In the Peace system, populations were found to have lower genetic distance between them (Thomas et al. 2001).

Historically, bull trout were distributed throughout a much greater area of Alberta than they are today (Figure 2). Populations occurred in both parkland and prairie regions (Berry 1994). They were once found downstream in the Peace River as far as the Slave River, as far east as Lethbridge in the Oldman River, as far east as Carseland in the Bow River, as far east as Morrin in the Red Deer River, and in Edmonton in the North Saskatchewan River (Brewin and Brewin 1997, McCart 1997). Anecdotal information and limited historical records suggest a large decline in distribution and abundance in all systems since the early 1900s (see Appendix 3) (Allan 1980, Brewin 1994a, Brewin 1994b, McCart 1997, Rhude and Stelfox 1997, Hvenegaard and Thera 2001). Brewin and Brewin (1997) provide detailed maps across the bull trout range in Alberta on a stream-by-stream basis, which illustrate where populations have declined or have been extirpated throughout the province.

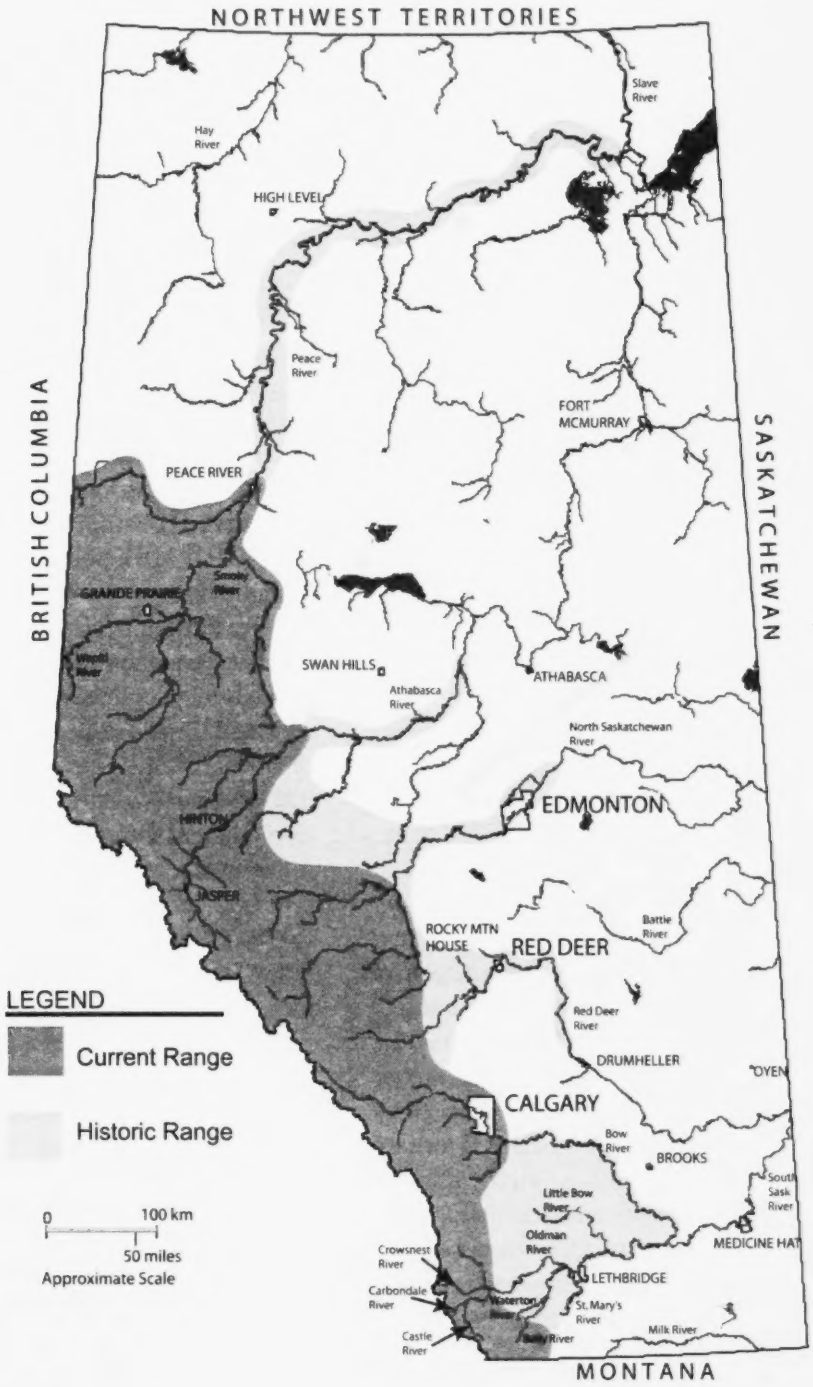

Figure 2. Historical and current distribution of bull trout in Alberta. Extracted from Brewin and Brewin (1997).

Today, bull trout occupy 20 000 km of stream habitat, and 12 000 ha of lake habitat in 24 lakes within Alberta (Berry 1994). They are generally confined to the upstream reaches of major river systems in the eastern slopes of Alberta (Peace, Athabasca, North Saskatchewan, Red Deer, Bow, and Oldman rivers). However, they do occur further from the mountains in the Peace and Athabasca drainages, but at lower abundances (Figure 2) (Berry 1994). Migratory adults may disperse as far east as Waterton-Glacier National Park (114°W) in Alberta and Montana (Haas and McPhail 1991).

2. Other Areas. - Globally, bull trout are distributed throughout the western mountains and foothills of Canada and the United States (Figure 3). Historically, bull trout were distributed as far south as California (41°N), and extended as far north as the Yukon River drainage (60-61°N) (Haas and McPhail 1991). Bull trout have been extirpated from California and Nevada and the southern extent of their range is now the Oregon-California border (42°N) (Haas and McPhail, 1991, Rieman et al. 1997, MBTRT 2000). The southern limit of bull trout distribution appears to be determined by temperature (Buchanan and Gregory 1997, MBTRT 2000), and populations appear to increase in abundance in northern parts of their range (Haas and McPhail 1991). In northwestern British Columbia, the bull trout does not extend to the coast; however, in the Puget Sound area, Washington, and the Fraser River, British Columbia, they do reach the coast (Haas and McPhail 1991). Their eastern boundary is at Waterton-Glacier National Park (114°W) in western Alberta and Montana, although historically, this may have been located further east. Bull trout have been declining throughout their global native range during the last century, leading to local extinctions and the isolation of remnant populations (Rieman and McIntyre 1995, Rieman et al. 1997, MBTRT 2000).

POPULATIONS SIZE AND TRENDS

1. Alberta. - Bull trout populations have been declining in Alberta over the last century (Appendix 3). Most self-sustaining (see glossary, Appendix 1) bull trout populations persist only in less accessible, headwater areas, such as Elk Creek (North Saskatchewan River drainage; Figure 4)). A number of populations have been extirpated in the last half century, including many populations in mountain lakes (Figure 5). Only remnant (see glossary, Appendix 1) populations have been located in either Jasper National Park or Waterton National Park, and only a few self-sustaining populations occur in Banff National Park (Brewin and Brewin 1997). Declines in population abundance have been more severe in southern areas of the province (Brewin and Brewin 1997). In the Bow River, large decreases in bull trout stocks were reported as early as the late 1930s, and more recent studies and creel (see glossary, Appendix 1) surveys have confirmed a continuing decline (Brewin 1994a). Today, bull trout are no longer present in large areas of the Oldman River sub-basin, and are self-sustaining in few rivers and streams in the Bow River system (Brewin and Brewin 1997). Bull trout are no longer found in most areas of the Red Deer River system. Declines in northern Alberta are less drastic; however, several populations have been extirpated from the Athabasca river drainage (Brewin and Brewin 1997). Bull trout were once common in the North Saskatchewan River near Edmonton, but have not been recorded there since the late 1950s (Brewin 1994b). In the Athabasca river drainage, all the major tributary systems still support self-sustaining populations (Brewin and Brewin 1997). A 1985 study estimated higher bull trout abundance than seen in the 1990s, suggesting that large declines may have occurred in the last 10-15 years with increased access to these remote areas (Brewin 1994b). Further north in the Smoky and Peace River systems, self-

Figure 3. Distribution of bull trout in North America. Extracted from Rieman et al. (1997).

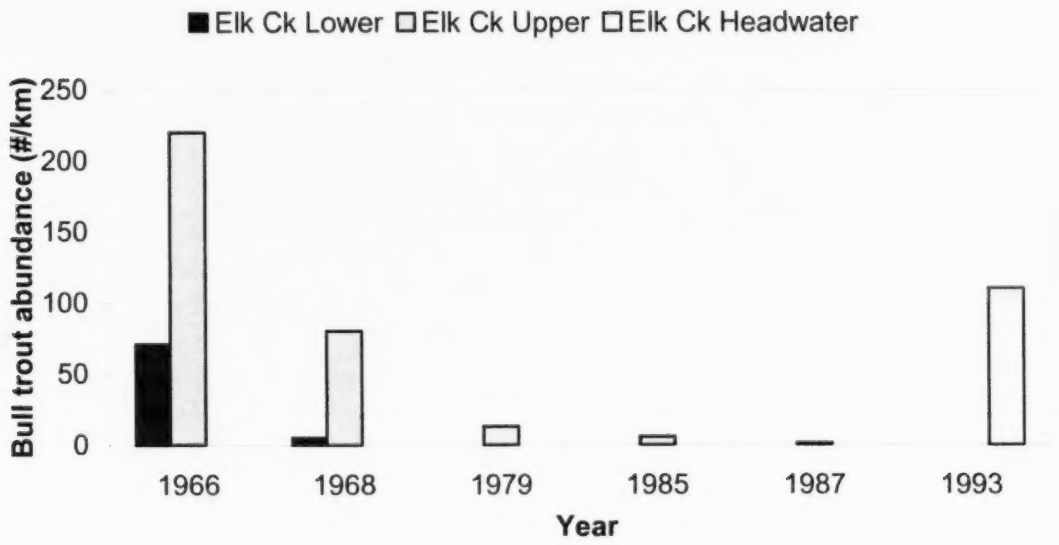

Figure 4. The abundance of a bull trout populations in various segments of Elk Creek, Upper Clearwater Drainage, Alberta, estimated from electrofishing surveys. Extracted from Rhude and Stelfox (1997).

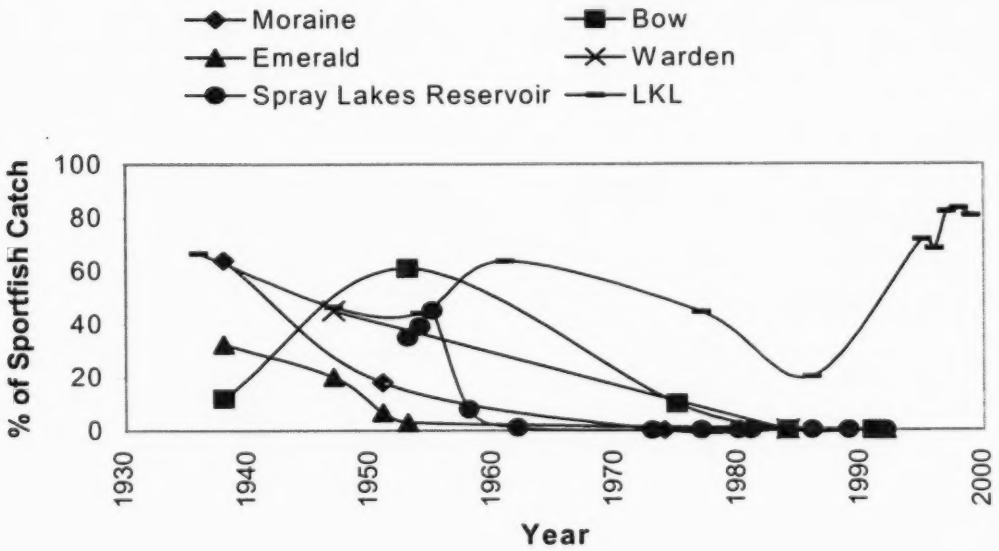

Figure 5. Population trends of bull trout in five mountain lakes in southern Alberta. Lines indicate the percent of the sport fish community composed of bull trout, from creel census and gill net surveys. Non-native *Salvelinus* species (brook trout and lake trout) were introduced into all lakes except Lower Kananaskis Lake (LKL). Extracted from Donald and Stelfox (1997), and Mushens and Post (2000).

sustaining populations are more common (Brewin and Brewin 1997).

Restrictive angling regulations were imposed in an attempt to halt declines of bull trout populations. In the Upper Clearwater drainage, limited population data suggest that populations may have increased slightly since the closure of spawning grounds in 1976 (Figure 6). In 1993, there was a 50% increase in the number of fish caught in traps in Timber Creek, Sawmill Springs and Forty Mile Springs (Rhude and Rhem, 1995). Fish displayed low spawning fidelity to these streams by using other streams within the same complex. A number of these additional springs were not located as spawning grounds until 1993, therefore limiting the ability to accurately describe population abundance. Decreased bag limits imposed in 1984 and minimum size limits imposed in 1987 may also have contributed to an increase in population size. No information is available for these areas after the zero-bag-limit was imposed throughout Alberta in 1995.

The total number of genetically distinct populations in Alberta today is difficult to estimate, but it is reasonable to suggest that the number is in the tens, but not likely in the hundreds. The total number of adult bull trout in Alberta lakes and streams has been roughly estimated at 11 000 to 15 000 (M. Sullivan, pers. comm.).

Zero-bag-limits and the closure of spawning grounds to angling appear to have had a positive effect on bull trout populations. A five-year trap collection of spawning adults and juveniles in Lynx Creek, Kakwa River drainage indicates a population increase since the 1995 zero-bag-limit and the permanent closure of Lynx Creek in 1997 to protect spawning habitat (Figure 7). It should be noted that the trap failed in 1997 and is therefore an incomplete data set (Hvenegaard and Thera 2001). A fluvial population in the North Belly River in southwestern Alberta also appears to have increased slightly since 1995 because of increases in the number of spawning fish and redd counts (Figure 8).

More stringent regulations have had similar impacts on adfluvial bull trout populations. Following the closure of spawning grounds in 1989, the Pinto Lake population increased from 56 spawning adults in 1982 to 323 in 1993 (Figure 9; Herman 1997). Different methods were used to catch these adults; however the method was standardized from 1988 (n=158) to 1993 (n=323) (Herman 1997). In Lower Kananaskis Lake, bull trout decreased from 11% of the reservoir's entire fish population in 1954 to 2% in 1986 (Stelfox 1997). The Lower Kananaskis Lake dam was built in 1955 and left 13 km of Smith Dorien Creek as the only suitable spawning habitat available to this population. The population declined to 60 spawning individuals by 1992. Since the new regulations were implemented in 1992, the spawning population has increased to 1370 individuals in 2000. Juvenile and redd counts have followed a similar trend (Figure 10; Mushens and Post 2000). Recent data may suggest the population is switching to an alternate year spawning strategy now that the population density has increased (Mushens and Post 2000). As a result, data collected on the number of spawning adults may provide an underestimate of the population size. Redd counts in Smith Dorien Creek mirror the trends observed in the spawning adult population (Mushens and Post 2000).

Quantitative information on the abundance and distribution of bull trout over decades is very limited. This makes it difficult to assess the overall extent of population declines, or even the current province-wide population. Anecdotal evidence is used to fill in the gaps

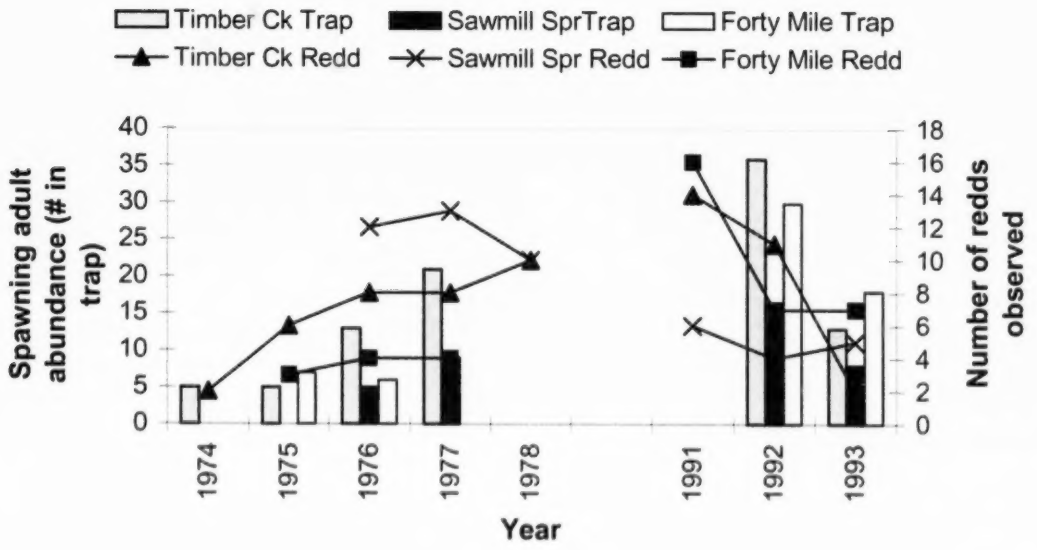

Figure 6. Bull trout population trends in Timber Creek, Sawmill Springs, and Forty Mile Springs, Upper Clearwater Drainage, Alberta (1974-1978, 1991-1993), demonstrating the importance of spawning fidelity in assessing populations. Bars indicate the number of spawning adults caught in an incline plane trap and points indicate the number of redds observed in the stream. Extracted from Rhude and Rhem (1995).

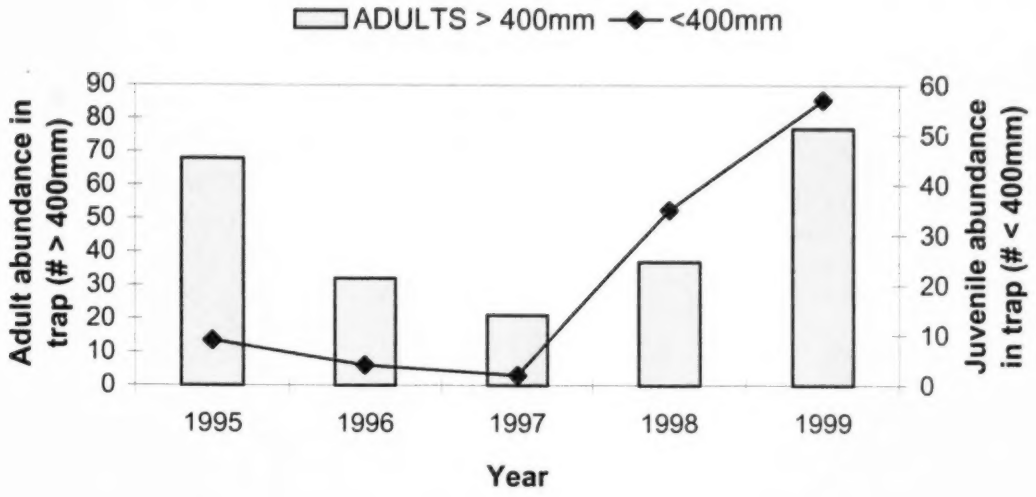

Figure 7. Bull trout population trends in Lynx Creek, Kakwa River Drainage, Alberta. Bars indicate the abundance of adults (> 400 mm) caught in a trap and points indicate the abundance of juveniles (< 400 mm) caught in the trap. Extracted from Hvenegaard and Thera (2001).

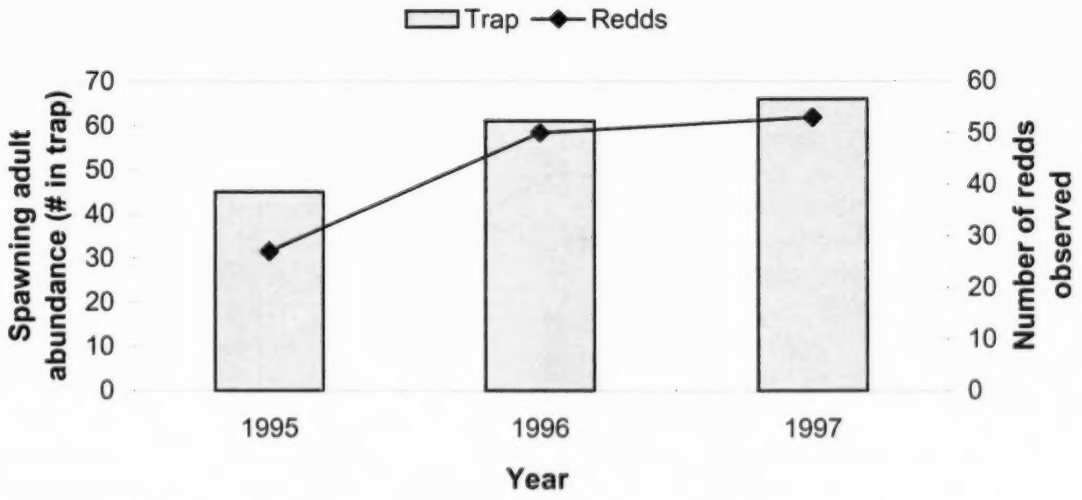

Figure 8. Bull trout population trends in the North Belly River, Alberta. Bars indicate the number of spawning adults caught in an incline plane trap and points indicate the number of redds observed in the stream. Extracted from Clayton (1998).

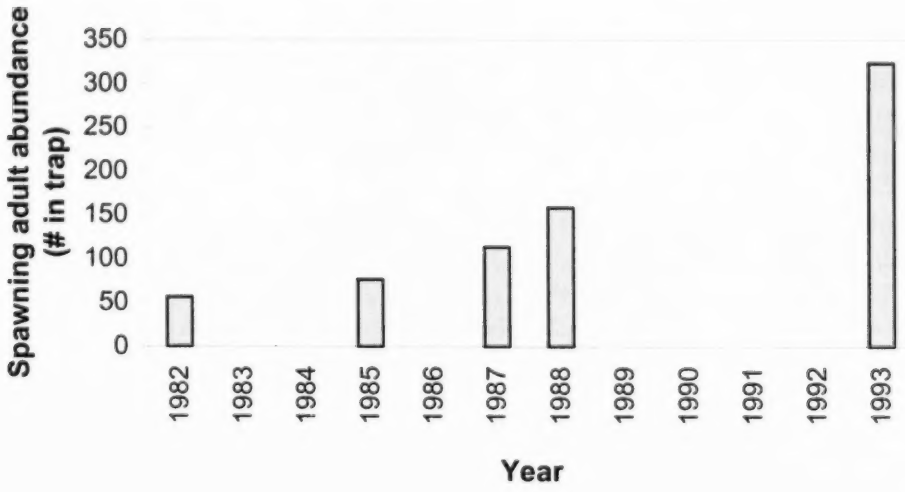

Figure 9. Bull trout population trends in Pinto Lake, Alberta. Bars indicate the number of spawning adults caught. Extracted from Herman (1997).

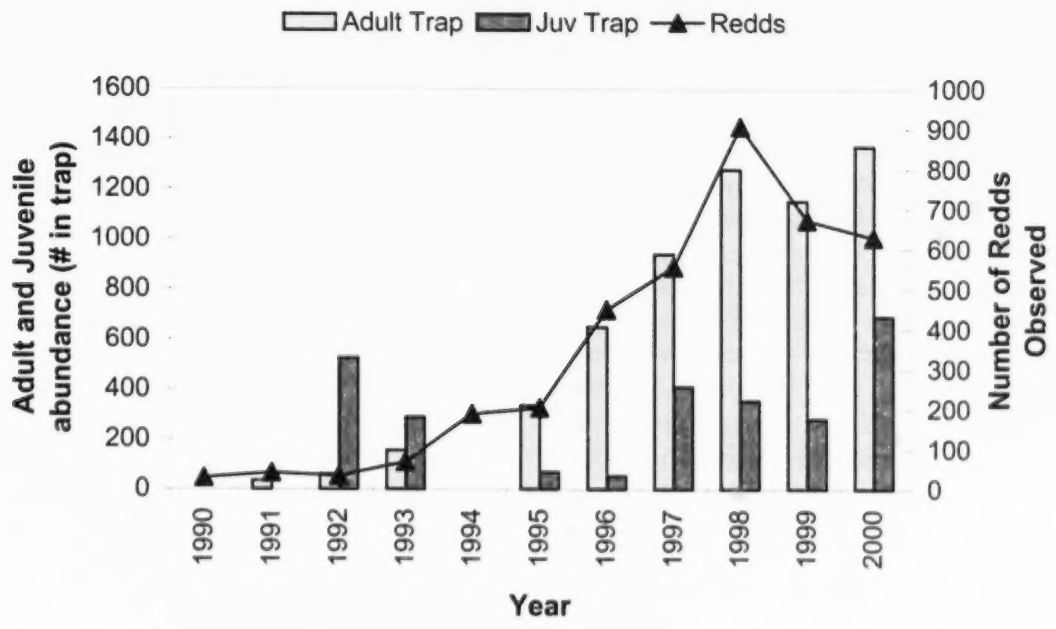

Figure 10. Bull trout population trends in Lower Kananaskis Lake before and after the zero-bag-limit was introduced in 1992. Bars indicate the number of spawning adults moving upstream and the number of juveniles moving downstream, that were caught in a trap. Points indicate the number of redds observed in Smith Dorien Creek. Extracted from Mushens and Post (2000).

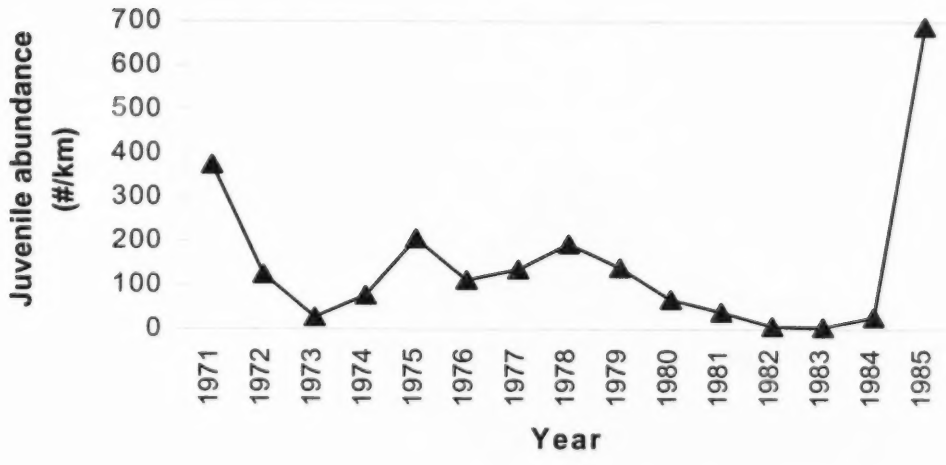

Figure 11. Estimates from electrofishing surveys of juvenile bull trout abundance in Eunice Creek, FMA4. Extracted from Hunt et al. (1997), and Paul et al. (2000).

in historical records. From the late 1960s to 1993, only a small percentage (~30%) of the rivers and streams in the Athabasca river drainage were surveyed. Only 28% of these included fish composition surveys and only 4% included population estimate studies (Hunt et al. 1997). Therefore, data that can be used to look at long-term population trends to support the anecdotal evidence of population declines are rare. Because of natural variation, large population declines often require more than ten years of data to detect these trends statistically (Rieman and Myers 1997, Maxwell 1999). Additionally, little is known about bull trout population dynamics under relatively unaltered conditions, except for a unique case in Eunice Creek (Athabasca river drainage) which was closed to angling in 1966 and protected from most development until 1985 (Hunt et al. 1997). Cyclical variation in abundance of juveniles was observed in this population and has been attributed to competitive interactions and cannibalistic behaviour (Figure 11; Paul et al. 2000). Fidelity to spawning grounds may alter population estimates with no actual change in population size. These factors make it more difficult to assess the status of the population from a few annual estimates.

If long-term data exist, they typically incorporate non-standardized sampling techniques reducing the comparability of the data (Baxter and Westover 1999). Night snorkeling is the most effective technique for the detection of juvenile bull trout, followed by electrofishing in streams (Bonar et al. 1997). Density estimates will be higher at night because bull trout emerge from cover during this time (Baxter and McPhail 1997, Goetz 1997a). Traps work well for estimating migratory populations, but redd counts are necessary for resident populations (Bonar et al. 1997). Monitoring redd counts for an index population may not be a good indicator of trends in a larger regional population (Rieman and McIntyre 1996). The reliability of redd counts decreases as density and turbidity increase (Bellerud et al. 1997, Mushens and Post 2000). Population surveys throughout Alberta and long-term population monitoring that follows standardized methodology is required to determine the true status of the bull trout population in the province.

2. Other Areas. - Bull trout populations have experienced declines in abundance in all areas of their native range (Brewin 1994a and 1994b, Brewin and Brewin 1997, Fitch 1997, McCart 1997, Rhude and Stelfox 1997, Earle and McKenzie 2001). Populations in British Columbia are considered vulnerable to declines because of their susceptibility to changes in habitat quality (Pollard and Down 2001). In the northwestern United States, more than 50% of populations have declined in abundance, and only 6% of the bull trout populations are considered stable or increasing (Howell and Rieman 1997, Rieman and Myers 1997, MBTRT 2000, Lohr et al. 2001). In the Columbia River basin, it is estimated that strong bull trout populations are only present in 6% of their potential range and 24% of potential spawning and rearing watersheds. Historical estimates are 12% and 44% respectively, which suggests that it is unlikely the whole range was ever occupied at once (Rieman et al. 1997).

LIMITING FACTORS

Many factors, both natural and human, limit the distribution and abundance of bull trout in Alberta (Appendix 4). Human activities result in habitat fragmentation, barriers to migration, habitat degradation, angling pressure, and the stocking of non-native fish species. These factors, combined with bull trout population dynamics, limit the species' abundance. As discussed previously, there is low genetic diversity within bull trout populations. To

decrease the risk of extinction of the metapopulation (see glossary, Appendix 1), the exchange of genetic material between local populations must occur (McCart 1997). Therefore, any factor that decreases the number of genetic sources, such as local extinctions or the blockage of genetic exchange between populations, may increase the risk of extinction of the entire bull trout population (Rieman and McIntyre 1995, McCart 1997, Rieman and Myers 1997, MBTRT 2000, Haas and McPhail 2001).

1. Migratory Barriers. - The construction of roads throughout Alberta to service mining, logging and fossil fuel industries has resulted in numerous blockages and hanging culverts which act as barriers to the migration of bull trout (Brewin 1994b, Hunt et al. 1997, MBTSG 1998). Mining may also result in stream blockages from extraction of alluvial mineral deposits near streams (Earle and McKenzie 2001). The biggest barrier to migration is the construction of dams. Dams block access to spawning and rearing habitat by isolating tributaries from spawning adults and juveniles as well as isolating populations (Goetz 1997b, Hansen and DosSantos 1997, MBTSG 1998). The Oldman Dam has no fish passage structure incorporated into it, and bull trout congregate below the dam to attempt spawning migration (Fernet and O'Neil 1997). Fish captured below and then released above the dam moved up the Castle River to spawn (Fernet and O'Neil 1997). Dams not only act as a physical barrier, but may also alter or withhold flows from areas that might otherwise have been accessible (Goetz 1997b, Hansen and DosSantos 1997, MBTSG 1998, Mogen and Kaeding 2000). Irrigation canals may also have the same effect (Hansen and DosSantos 1997, McCart 1997, Clayton 1998, MBTSG 1998). Twenty percent of mortality in the Belly and Waterton river drainages was attributed to entrainment (see glossary, Appendix 1) in irrigation canals or the blockage of upstream movement (Clayton 1998). Migratory movements may also be blocked by beavers, with their dams acting as physical barriers and withholding flow from otherwise suitable habitat (Brewin 1994b, McCart 1997, Rhude and Stelfox 1997).

2. Habitat Degradation and Fragmentation.- Human activities degrade bull trout habitat in numerous ways. Activities such as residential and industrial development, mining, grazing, agriculture, irrigation, dams, road construction, and recreational development may all decrease the stability and the complexity of the aquatic habitat (McCart 1997, MBTSG 1998). Removal of riparian vegetation, the erosion of stream banks, removal of large woody debris and coarse substrates, and channel alterations are all disturbances created by these activities (Cross and Everest 1997, McCart 1997, MBTSG 1998).

Mining, logging, agriculture, irrigation, dams and recreational development often result in the alteration of surface and groundwater flows (MBTSG 1998). Logging can result in faster runoff events and flooding as well as cause changes in the groundwater recharge and seasonal flows (Berry 1994, Cross and Everest 1997, McCart 1997, MBTSG 1998). Large fluctuations in water flow, both in the outlet as well as within the reservoir itself may have implications to the habitat utilized by bull trout. In Lower Kananaskis Lake, the surface area of the lake at draw-down is only 44% of bankfull, which impacts the presence and production of the littoral zone within the reservoir, and during flooding causes re-suspension of sediment (Golder Associates Ltd. 1995). Stabilization would likely increase bull trout production three-fold (J.R. Post, unpubl. data).

Logging, mining, road construction, grazing, agriculture, and recreational development may cause sediment accumulation in bull trout waters (Berry 1994, Cross and Everest 1997, McCart 1997, MBTSG 1998). A study

conducted on managed and unmanaged watersheds, suggests that sediment was carried from harvested forest areas with a high density of roads and accumulated in the stream reducing the habitat complexity and carrying capacity of the stream (Cross and Everest 1997).

The presence of beaver also limits bull trout distribution. The construction and destruction of old beaver dams may increase sediment loads (Fairless et al. 1994). This may increase the mortality of incubating eggs and young and alter the carrying capacity of the stream by destroying suitable habitat (Fairless et al. 1994, Cross and Everest 1997).

Stream temperature is affected by human activities. Road construction, timber harvest, grazing, agriculture and recreational development all decrease the canopy cover and cause increased thermal loading (Berry 1994, Adams and Bjornn 1997, McCart 1997, MBTSG 1998). Removal of water, and containment in dams and irrigation structures also alters the thermal regime (Goetz 1997b, MBTSG 1998). The elimination of bull trout in California is attributed to an increase in temperatures as a result of dam construction (Adams and Bjornn 1997). Mining, irrigation, urban development, and agriculture all have impacts on the water quality, either causing direct mortality or altering food supplies (McCart 1997, McLeod and Clayton 1997, MBTSG 1998). Loss of habitat complexity, increased sediment load and increased temperatures may also occur during wildfires. However, fires tend to leave refugia, and may even enhance the habitat by increasing large woody debris and pools (Ratcliff et al. 1996, MBTSG 1998).

3. Angling Pressure and Fisheries Management Practices. - In the last 50 years, angler access to bull trout habitat has increased dramatically because of road construction for forestry, mining, seismic and fossil fuel industries (Rhude and Stelfox 1997, Walty and Smith 1997, Paul 2000, Post and Paul 2000). Overharvest from angling has been one factor responsible for the decline in bull trout abundance. Historically, bull trout were considered a piscivorous, "junk" fish and active eradication plans were carried out in the 1920s (Colpitts 1997). Anglers would toss them in the bushes to rot (Van Tighem 1997), and during the depression they were overexploited because they were an easy food source (Allan 1980). In the late 1960s, four lakes in the Athabasca river drainage that contained bull trout were treated with a fish toxicant, rotenone (Hunt et al. 1997).

Attitudes, management practices, and regulations have changed, however, poaching is still a problem. It is estimated that 5% of the mortality in the Belly and Waterton Rivers is a result of poaching (Clayton 1998). In Montana, poaching rates through the summer were estimated at 5 bull trout/day, and 22 fish/week (Long 1997). Poachers prefer the snagging technique which is a more damaging method of fishing and results in a high mortality of escaped fish (Long 1997). Unfortunately, the manpower and resources are not available for enforcement. In addition, a 1993 Alberta poll indicates that misidentification of bull trout with non-native fish occurs fairly frequently, indicating public education is required (Boxall and LeFrancois 1997).

In the 1950s, unrestricted anglers were catching 15-21 fish/day in the Clearwater drainage. In a study done on the Athabasca in 1992-1993, 17-22% of tagged fish were caught and killed by anglers (McLeod and Clayton 1997). However, even in catch-and-release fisheries, mortality can occur. Mortality from hooking in the Belly and Waterton Rivers was estimated to be 5% (Clayton, 1998). In the Wigwam

River, British Columbia, it was estimated that 64% of the bull trout spawning population was caught before or after the event, and that a minimum of 79% of these fish survived this catch-and-release (Westover 1999). Bull trout population and fisheries model (BULLSim v2.0) simulations demonstrate that bull trout populations can not be sustained without restrictive angling regulations given reasonable estimates of catch-and-release mortality, illegal harvest, and fishing effort (Post and Paul 2000). Key biological uncertainties in our ability to reliably predict sustainable fishing pressure include juvenile growth, survival and recruitment (Thera et al. 2001). The presence of other introduced sports fish might increase the mortality of bull trout because of the incidental by-catch of bull trout by anglers targeting other trout species (McIntyre 1998, Post and Paul 2000).

The bull trout is particularly susceptible to overexploitation. Compared to other freshwater sport fishes, they are particularly slow-growing and late to mature. In addition, they are more vulnerable to angling compared to other species, especially when bait is used, because of their opportunistic and aggressive behaviour (Berry 1994, Brewin 1994a, Van Tighem 1997, Paul 2000, Post and Paul 2000). Because of their high vulnerability, bull trout populations are susceptible to overharvest even at low levels of angling effort (Paul 2000, Post and Paul 2000, Sullivan 2001). Spawning migrations may also involve staging periods at the mouths of tributaries, or collection beneath barriers to migratory movements may occur (Ratcliff et al. 1996, Bellerud et al. 1997, Fernet and O'Neil 1997, McCart 1997, Westover 1999, Mushens and Post 2000). A concentration of large fish in shallow, clear-water areas makes bull trout very susceptible to angling pressure.

4. Non-native Fish Species Introduction. - Non-native fish species that have been introduced to numerous systems in Alberta cause declines and extirpation of bull trout, reduced growth and survival and changes in the aquatic community (Appendix 3) (Fitch 1997, McCart 1997). Non-native fish that have been introduced into Alberta drainages include the following: brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), and lake trout (*Salvelinus namaycush*).

Brown trout spawn later than bull trout and may disturb redds (Rhude and Stelfox 1997). On the other hand, bull trout and brook trout have similar spawning requirements, which results in competition for spawning habitat, and the risk of hybridization (Berry 1994, Ratcliff et al. 1996). It is generally assumed that these hybrids are sterile (Berry 1994); however, there has been some evidence that they are able to reproduce (Buktenica 1997). Donald and Stelfox (1997) proposed that the introduction of other *Salvelinus* species results in the competitive exclusion of bull trout, while *Oncorhynchus* species allow for sympatry (Appendix 3). In the areas in southwestern Alberta where brook trout have been introduced, approximately 70% of the native bull trout populations have been, or are thought to have been, extirpated (Fitch 1997). Brown trout did not cause extirpation in the one system where it was the sole introduced species present, but extirpation did occur when brook and brown trout were both present (Fitch 1997).

Temperature may play an important role in determining the extent that non-native fish invade, with species establishing dominance in a shorter time when they are in situations closer to their thermal optimum (Adams and Bjornn 1997, Haas 2001). The relationship between the distribution of non-native fish species and elevation was found to be a negative one that could not be explained by stocking location (Post and Paul 2000). Elevation is highly correlated with temperature, and the low temperatures associated with the

bull trout habitat may lead to lower growth rates compared to other salmonids, however; they do discourage the invasion of other species with higher temperature requirements preventing competitive exclusion (MBTRT 2000). Bull trout are displaced to these thermal refugia in headwater areas by competition with some non-native fish species (Donald and Alger 1993, Post and Paul 2000).

Slower growth, late maturity, and alternate year spawning are all factors that make bull trout more susceptible to competition with non-native fish species, resulting in reductions in abundance and population viability (Berry 1994, Hunt et al. 1997, McCart 1997). Earlier maturing brook trout populations grow more rapidly, which may allow sneaking behaviour and hybridization, further limiting bull trout spawning success (Ratcliff et al. 1996, Bellerud et al. 1997, Paul 2000, Post and Paul 2000).

The genetic uniqueness of bull trout populations also makes stocking and hatchery production an unattractive management plan, therefore the transfer of fish between drainages should be avoided (Kanda et al. 1997, McCart 1997). It is likely that a combination of these limiting factors has resulted in the large declines that have been seen in bull trout populations over the last century.

5. Genetics. - Reproductive isolation of bull trout populations occurs because of their generally high fidelity to spawning areas (Allan 1980, Rieman and McIntyre 1996, Bellerud et al. 1997, Rieman and Myers 1997). The low genetic diversity within populations, and the high genetic divergence that occurs between populations is evidence of this (Bellerud et al. 1997, Kanda et al. 1997, Williams et al. 1997, Taylor et al. 2001, Thomas et al. 2001). These genetically distinct units are stocks that result from evolutionary divergence because of local environments. Over time, the loss of genetic variability, may result in a decrease in the populations viability. Therefore, exchange of genetic material between populations must occur (MBTSG 1996). Attempts to maintain population fragments caused by human disturbance may not ensure their persistence. These populations must be managed on both a local and regional scale considering their genetic uniqueness and their connectivity (Rieman and McIntyre 1996, Bellerud et al. 1997).

Effective population size is related to the rate of loss of genetic diversity. Geneticists' estimates of the minimum population size required to maintain long-term genetic diversity varies, and these estimate vary with the level of isolation of these populations (Brewin 1994a, Ratcliff et al. 1996, Rieman and Allendorf, in press). Estimates of 50 to 500 represent the minimum number of spawning individuals required to prevent excessive rates of inbreeding in the population (Brewin 1994a, Ratcliff et al. 1996). Recent results from modeling simulations indicate that different life histories, overlapping generations, alternate year spawning, different ages of maturity and longevity may all affect the effective population size required (Rieman and Allendorf, in press). It was determined in a recent model that populations with 1000 breeding adults would maintain genetic diversity indefinitely, and 100 spawning adults would minimize the risks of inbreeding. However, bull trout populations as large as 1000 breeding individuals are relatively uncommon, therefore managers must recognize that more common, smaller populations are more at risk. The connection of populations within a metapopulation may enhance the maintenance of genetic diversity in more than an additive way, but the fragmentation of these populations may result in an accelerated loss of genetic diversity (Rieman and Allendorf, in press).

Minimum population sizes are difficult to predict for migratory populations of fluvial bull trout. In addition, delimiting the population size and range is difficult when migratory movement exceeds hundreds of kilometers. Rieman and McIntyre (1996) found redd numbers or rate of change in redd numbers to be weakly correlated with distance even within basins. This suggests that monitoring limited areas may not indicate trends in all local populations. The conservation of different life history strategies is key to the persistence of viable populations on both a local and regional scale (Fitch 1997, Rieman and Clayton 1997, MBTRT 2000). It is these strategies that allow for the exchange of genetic material between localized and genetically distinct populations. However, little is known about the rate of genetic exchange within and between watersheds. As a result of human-caused habitat fragmentation, remaining bull trout populations are restricted to smaller, more isolated areas, making genetic exchange more difficult, if not impossible (Rieman et al. 1997). Further habitat loss may result in an acceleration of extinction rates above the rate of habitat loss (Rieman et al. 1997). More information is required to better define local populations and the population abundance required to produce viable populations. Genetic exchange between local populations and its role in sustaining both local sub-populations and the metapopulation are also important. Current land use practices and fisheries management strategies have not been able to adequately maintain viable populations in Alberta and throughout the species' range.

STATUS DESIGNATIONS

1. Alberta. - The decline of bull trout populations in Alberta since the turn of the century led to a reappraisal of their status within Alberta. According to *The General Status of Alberta Wild Species 2000*, bull trout are considered "Sensitive" in the province (Alberta Sustainable Resource Development 2001a, b). The Alberta Natural Heritage Information Centre ranks bull trout as S3 (see Appendix 2 for status definitions), and states that their status within Alberta needs to be verified (ANHIC 2001).

2. Other Areas. - The bull trout's Global Heritage Status rank is G3 (see Appendix 2 for status definitions; NatureServe 2001). The Committee On the Status of Endangered Wildlife in Canada (COSEWIC) has not yet evaluated bull trout (COSEWIC 2001), although this species is on their candidate list (R.A. Campbell, pers. comm.). *The General Status of Species in Canada* lists the bull trout as "Sensitive" in British Columbia and the Yukon and "May Be At Risk" in the Northwest Territories (Canadian Endangered Species Conservation Committee 2001). The British Columbia Conservation Data Centre (2001) ranks the bull trout as S3, "Blue-listed", because of declining populations in the province (Pollard and Down 2001). In addition, the species was listed in *Identified Wildlife Strategy Guidelines* 1999 under the Forestry Practices Code of British Columbia, which recommended special protection measures (Pollard and Down 2001).

In the United States, bull trout are currently listed as "Threatened" throughout their range (lower 48 states), by the United States Fish and Wildlife Service (USFWS), under the Endangered Species Act (USFWS 2001, Lohr et al. 2001). The first formal designation of bull trout as a species of concern was in 1985, when the USFWS designated them a "Category 2" taxon. This indicated that there was insufficient evidence to demonstrate bull trout were susceptible to threats (Lohr et al. 2001). This status was further upgraded to a "Category 1" in November 1994, as more information on the biological vulnerability of bull trout became

available. After listing various populations of bull trout as "Threatened", the USFWS listed the last population segments within their range in the United States as "Threatened" in 1999 (Lohr et al. 2001). The designation of bull trout as a species of "Special Concern" was first given to bull trout by the American Fisheries Society in 1987 (Brewin 1994a, Rhude and Stelfox 1997). The Montana Natural Heritage Program (2001) also designates bull trout as a species of "Special Concern".

RECENT MANAGEMENT IN ALBERTA

Angling regulations regarding bull trout started to become more restrictive in 1976, when some critical spawning and rearing habitats were closed to angling. Streams above and including Timber Creek, in the Clearwater drainage were closed at this time (Rhude and Rhem 1995, Rhude and Stelfox 1997). In 1984, harvest limits were reduced from five bull trout/day to two bull trout/day, and in 1987 the minimum harvestable size of 40 cm was implemented province-wide (Rhude and Stelfox 1997). In the Athabasca river drainage, fluvial and resident populations may not have been able to sustain this lowered rate of harvest (Hunt et al. 1997). Rhude and Rhem (1995), found that since 1976 the spawning population has only increased by 70% in the Upper Clearwater River over a period of 25 years.

The large body size of fluvial and adfluvial bull trout at first maturity has important implications to minimum size for harvest regulations, since a 40 cm limit may allow for the capture of immature fish (Berry 1994). Migratory populations may not achieve maturity before they enter the vulnerable size category of the angling regulations. This decreases spawning potential and causes a decline in the number of juveniles, a decline in the number of spawning individuals, as well as a further decline in population abundance. Stelfox (1997) found that 70% of the legal-sized fish caught during the winter of 1991 and 1992 in Lower Kananaskis Lake were immature. It was further estimated that one-half of the adult population was harvested during that single winter fishery. Therefore, in April 1992, Smith Dorien Creek and the northwest bay in Lower Kananaskis Lake were closed to fishing, and a zero-bag-limit was imposed in all other areas of the lake (Stelfox 1997, Mushens and Post 2000). As noted previously, the spawning population has increased from 60 adults in 1992 to 137 adults in 2000 (Mushens and Post, unpubl. data). Similarly, Pinto Lake, its tributaries, and 1.5 km of its outlet were closed to fishing, and after five years of closure bull trout populations appeared to be increasing (Herman 1997, Rhude and Stelfox 1997).

On April 1, 1995, a zero-bag-limit for bull trout was implemented throughout Alberta by the Natural Resources Service, Alberta Environment (Hvenegaard and Fairless 1998). In addition, in response to increased information on bull trout life history strategies and migratory behaviour, the fall in-stream 'no activity' window was adjusted to include the month of August (Hvenegaard and Thera 2001). However, this cannot control mortality from hooking, misidentification, ignorance of regulations, and poaching (McCart 1997).

Bait bans were introduced to most flowing waters in the foothills of Alberta to decrease hooking mortality (Berry 1994). The results of a 1993 poll indicate that the ability of anglers to identify bull trout is low, suggesting that angler education may be a serious problem (Boxall and LeFrancois 1997). An education and enforcement program in Grand Cache (Muskeg River), Alberta, resulted in a decrease in number of bull trout seizures by 88% from 1992 to 1993, a decrease of 39% in detected

violations, and more educated anglers with 71% releasing all bull trout caught (Ramstead 1997). Although bull trout are separated from other trout species in the 1993 Alberta sportfishing regulations, there was little information on recovery plans for this species to aid in further education and awareness (Berry 1994). In 1994, Alberta Fish and Wildlife produced *Alberta's Bull Trout Management and Recovery Plan* (Berry 1994). This document discusses angling regulations, public education, development of recovery plans, and enforcement, as well as management changes in 1995 and aspirations for the year 2000. As a result of this plan, initiatives were launched to increase public support for bull trout recovery. These initiatives included the following; bull trout as an official emblem of Alberta, poster and signage campaigns, use of Public Service Announcements, promotion of bull trout conservation through media, and educational contests such as the historic photo contest (Brewin 1997). A critical review of the degree of success of the bull trout management program of the late 1990s, spurred by Berry's (1994) "Management and Recovery Plan", is needed.

Non-native fish have a negative effect on bull trout populations and the removal of these species is one management option. In Quirk Creek, on the upper Elbow River, a pilot study was conducted to determine if anglers could decrease the abundance of brook trout and therefore, increase bull trout populations (Paul 2000, Post and Paul 2000). The results from a predictive model suggest that, because of the resiliency of brook trout and the high catchability of bull trout resulting in hooking mortality, this management technique may not succeed (Paul 2000, Post and Paul 2000). This experimental management program is ongoing and should provide useful information on its feasibility within the next two years. In the United States, the removal of non-native species by electrofishing and piscicide, in areas downstream of the bull trout populations, were examined and initial results suggest some success (Buktenica 1997). In another pilot study, a special culvert was installed that limited brook trout access to bull trout spawning areas, but allowed bull trout passage (Brewin 1994a, Buktenica 1997). Further experimental studies of this kind should be conducted to test various management options.

SYNTHESIS

Bull trout populations in Alberta have been declining since the early 1900s. Although this decline has been more drastic in southern parts of the province, anecdotal evidence and limited historical records indicate that a decline has occurred throughout the bull trout's native Alberta range. To more clearly define bull trout status in the province, long-term monitoring programs must be initiated to determine if this decline has been halted by management initiatives or if incremental extirpations continue. Not only will this information help determine the current status of bull trout in Alberta, but may also aid in directing bull trout conservation and management in the future.

An understanding of bull trout biology is still limited because of its complex life history strategies, and the lack of research that has been conducted on this species historically. Much of the information on bull trout has been inferred from other salmonid species, and little is known about why specific life history strategies are expressed. Information on juvenile bull trout presence and abundance in many rivers and lakes is unavailable, and little is known about their migratory patterns. Habitat requirements and timing for each life history strategy in all stages of growth are still not clearly understood, nor is the extent of their fidelity to spawning streams, or their spawning strategy. Therefore, it is difficult for managers

to assess potential impacts of industrial development and human activity on this species. Further research is required to assess the potential impacts that habitat disturbance and loss has on bull trout populations and their long-term viability.

The maintenance of the genetic uniqueness of each bull trout population is a difficult management problem. Regional management plan must be created to ensure the long-term viability of the species as well as the persistence of local populations. Additional research is required to better understand the genetic distinction of each population, the rate of exchange of genetic material between populations, and the significance of this exchange to the overall viability of the species in Alberta. This is complicated by the hybridization of bull trout with introduced species. The viability of these hybrids in natural systems is unclear, and the mechanisms by which these non-native fish species interfere with bull trout population growth needs to be more clearly understood. Pilot studies that attempt to mitigate the factors limiting bull trout populations are being carried out. These should be examined for their feasibility within Alberta. Bull trout are not immediately at risk of extirpation in Alberta; however, history clearly demonstrates how vulnerable local populations are to habitat disturbance, overfishing, and interactions with non-native fish species. If current trends continue, bull trout will only persist in the upper reaches of undeveloped watersheds or will be completely extirpated if human development eliminates these refuges.

LITERATURE CITED

Adams, S.B. and T.C. Bjornn. 1997. Bull trout distributions related to temperature regimes in four central Idaho streams. Pp. 371-380 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Alberta Fish and Wildlife. 1985. A policy for the management of threatened wildlife in Alberta. Alberta Fish and Wildlife, Edmonton, AB. 34 pp.

Alberta Fish and Wildlife. 1991. The Status of Alberta Wildlife. Alberta Forestry, Lands, and Wildlife, Wildlife Management Branch, Edmonton, AB. 49 pp.

Alberta Natural Heritage Information Network. 2001. Elements on the Tracking List. Alberta Natural Heritage Information Centre (ANHIC). URL: http://www3.gov.ab.ca/env/parks/anhic/anhic.html [Revision date: 15 May 2001].

Alberta Sustainable Resource Development. 2001a. The General Status of Alberta Wild Species 2000. Alberta Sustainable Resource Development, Fish and Wildlife Service, Edmonton, AB 46 pp.

Alberta Sustainable Resource Development. 2001b. Fish: Preliminary Status Ranking Forms. The General Status of Alberta Wild Species 2000. Prepared for Alberta Sustainable Resource Development, Fish and Wildlife Division, Edmonton, AB. 81 pp.

Alberta Wildlife Management Division. 1996. The Status of Alberta Wildlife. Alberta Environmental Protection, Wildlife Management Division, Edmonton, AB. 44 pp.

Allan, J.H. 1980. Life history notes on dolly varden char (*Salvelinus malma*) in the Upper Clearwater River, Alberta. Unpubl. rept. prepared for Fish and Wildlife Division, Alberta Energy and Natural Resources, Red Deer, AB. 57 pp.

Anonymous. 1994. Alberta's threatened wildlife: Bull trout. Alberta Environmental Protection, Fish and Wildlife, and Trout Unlimited Canada. Alberta Fish and Wildlife Services, Fisheries Management Division, Edmonton, AB. 4 pp.

B.C. Conservation Data Centre. 2001. Tracking Lists. British Columbia Ministry of Environment, Lands and Parks. URL: http://www.elp.gov.bc.ca/rib/wis/cdc [Revision date: 19 April 2001].

Baxter, J.S., and J.D. McPhail. 1997. Diel microhabitat preferences in juvenile bull trout in an artificial stream channel. North American Journal of Fisheries Management. 17: 975-980.

Baxter, J.S., E.B. Taylor, R.H. Devlin, J. Hagen, and J.D. McPhail. 1997. Evidence of natural hybridization between dolly varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) in a northcentral British Columbia watershed. Canadian Journal of Fisheries and Aquatic Sciences. 54: 421-429.

Baxter, J.S, and W.T. Westover. 1999. Wigwam River bull trout – Habitat Conservation Trust Fund Progress Report (1998). Fisheries Project Report KO 55. Viii + 21 pp. + 1 app.

Bellerud, B.L., S. Gunkel, A.R. Hemmingsen, D.V. Buchanan, and P.J. Howell. 1997. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon. Project No. 95-54 and Contract No. 94BI34342. 1996 Annual Report for U.S. Department of Energy, Bonneville Power Administration, Portland, OR, USA. 54 pp.

Berry, D.K. 1994. Alberta's bull trout management and recovery plan. Alberta Environmental Protection, Fish and Wildlife Services, Fisheries Management Division, Edmonton, AB. 22 pp.

Blake, T. 1997. Reclaiming a legacy: Trout Unlimited Canada and bull trout. Pp. 21-24 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, es.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Boag, T.D. and J.P. Hvenegaard. 1997. Spawning movements and habitat selection of bull trout in a small Alberta foothills stream. Pages 317-324 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Bonar, S.A., M. Divens, and B.Bolding. 1997. Methods of sampling the distribution and abundance of bull trout/dolly varden. Washington Department of Fish and Wildlife, Fish Management Program, Inland Fisheries Investigations, Resource Assessment Division, Olympia, WA. Report # RAD97-05. 48 pp.

Boxall, P.C., and R. LeFrancois. 1997. A survey of Alberta anglers' attitudes towards bull trout and fisheries management. Pages 45-52 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Brewin, M.K. 1994a. 1993 fishery investigations in the Upper Bow River system, Banff National Park, Alberta. For Ecosystem Management, Banff National Park Warden Service, Banff, Alberta. Prepared by Trutta Environments and Management, Cochrane, AB. 63 pp. + 3 app.

Brewin, M.K. 1994b. Identification of bull trout populations in the McLeod, Wildhay, Berland, and Muskeg River systems, Alberta. Draft prepared for Trout Unlimited Canada, Calgary; and Foothills Model Forest Program, Hinton, Alberta. Prepared by Trutta Environments and Management, Cochrane, AB. 47 pp. + 1 app.

Brewin, M.K., 1997. The Bull Trout Task Force (Alberta). Pp. 1-14 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Brewin, P.A. and M.K. Brewin. 1997. Distribution maps for bull trout in Alberta. Pp. 209-216 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

British Columbia Conservation Data Centre. 2001. Tracking Lists. British Columbia Ministry of Environment, Lands and Parks. URL: http://www.elp.gov.bc.ca/rib/wis/cdc/ [Revision date: 10 November 2000].

Buchanan, D.V. and S.V. Gregory. 1997. Development of water temperature standards to protect and restore habitat for bull trout and other cold water species in Oregon. Pp. 119-126 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Buktenica, M.W. 1997. Bull trout restoration and brook trout eradication at Crater Lake National Park, Oregon. Pp. 127-136 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Burrows, J., T. Euchner, and N. Baccante. 2001. Bull trout movement patterns: Halfway River and Peace River progress. Pp. 153-157 in Bull Trout II Conference Proceedings (Brewin, M.K. and M. Monita, eds). c/o Trout Unlimited Canada, Calgary, AB.

Canadian Endangered Species Conservation Council (CESCC). 2001. Wild Species 2000: The General Status of Species in Canada. Ottawa: Minister of Public Works and Government Services Canada.

Cavendar, T.M. 1978. Taxonomy and distribution of bull trout, *Salvelinus confluentus* (Suckley), from the American northwest. California Fish and Game. 64: 139-174.

Clayton, T. 1999. Fish collection in the Upper Belly River, Alberta, 1999. Alberta Conservation Association, Lethbridge, AB. 9 pp.

Clayton, T. 1998. 1996 & 1997 bull trout (*Salvelinus confluentus*) investigations in the Belly and Waterton River drainages in Alberta. Alberta Conservation Association, Lethbridge, AB. IX + 62 pp. + 4 apps.

Colpitts, G.W. 1997. Historical perspectives of good vs. evil: stream eugenics and the plight of Alberta's bull trout: 1900-1930. Pages 31-36 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

COSEWIC. 2001. Species at Risk in Canada. Committee on the Status of Endangered Wildlife in Canda. URL: http://www.speciesatrisk.gc.ca/Species/sar/main.htm [Revision date: 27 April 2001].

Connor, E., D. Reiser, K. Binkley, D. Paige, and K. Lynch. 1997. Abundance and distribution of an unexploited bull trout

population in the Cedar River watershed, Washington, USA. Pp. 403-412 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Cross, D. and L. Everest. 1997. Fish habitat attributes of reference and managed watersheds, with special reference to the location of bull trout (*Salvelinus confluentus*) spawning sites in the upper Spokane River ecosystem, northern Idaho. Pp. 381-386 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Dambacher, J.M. and K. Jones. 1997. Stream habitat of juvenile bull trout populations in Oregon and benchmarks for habitat quality. Pp. 353-360 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Donald, D.B. and D.J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology. 71: 238-247.

Donald, D.B. and J.D. Stelfox. 1997. Effects of fisheries management on adfluvial bull trout populations in mountain lakes of southern Alberta. Pages 227-234 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Dunham, J.B. and B.E. Rieman. 1999. Metapopulation structure of bull trout: influences of physical, biotic, and geometrical landscape characteristics. Ecological Applications. 9: 642-655.

Earle, J.E., and J.S. McKenzie. 2001. Habitat use by juvenile bull trout in mountain streams in the Copton Creek drainage, Alberta, and its relation to mining activity. Pp. 121-128 in Bull Trout II Conference Proceedings (Brewin, M.K. and M. Monita, eds.). c/o Trout Unlimited Canada, Calgary, AB.

Fairless, D.M., S.J. Herman, and P.J. Rhem. 1994. Characteristics of bull trout (*Salvelinus confluentus*) spawning sites in five tributaries of the Upper Clearwater River, Alberta. Fish and Wildlife Services, Alberta Environmental Protection, Rocky Mountain House, AB. 49 pp.

Fernet, D.A. and C.P. Bjornson. 1997. A Delphi analysis of bull trout habitat preference criteria with comparison to information collected from Smith-Dorien Creek, Alberta. Pp. 435-442 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Fernet, D.A. and J.O. O'Neil. 1997. Use of radio telemetry to document seasonal movements, and spawning locations for bull trout in relation to a newly created reservoir. Pp. 427-434 in Friends of the Bull Trout Conference Proceedings

(Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Fitch, L.A. 1997. Bull trout in southwestern Alberta: notes on historical and current distribution. Pp. 147-160 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Fox, E.N., T.B. Clayton, and K.J. Van Tighem. 1996. 1995 bull trout investigations in the Belly and Waterton River drainages: Final Report. Prepared for Waterton Lakes National Park and Alberta Fisheries Management Enhancement Program, Lethbridge, AB. Waterton Lakes National Park, Waterton Lakes, AB. 63 pp.

Giles, M.A., and M. Van der Zweep. 1996. Dissolved oxygen requirements for fish of the Peace, Athabasca and Slave River basins: A laboratory study of bull trout (*Salvelinus confluentus*) and mountain whitefish (*Prosopium williamsoni*). Northern River Basins Study, Edmonton, AB. Report no. 120. 153 pp.

Goetz, F.A. 1989. Biology of the bull trout, (*Salvelinus confluentus*), a literature review. Eugene, OR: U.S. Department of Agriculture, Forest Service, Willamette National Forest. 53pp.

Goetz, F.A. 1997a. Habitat use of juvenile bull trout in Cascade mountain streams of Oregon and Washington. Pages 339-352 in Friends of the Bull Trout Conference Proceeding (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Goetz, F.A. 1997b. Distribution of bull trout in Cascade mountain streams of Oregon and Washington. Pages 237-248 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Golder Associates Ltd. 1995. Review of the effects of reservoir operation on the productivity of Lower Kananaskis Lake. Draft. Prepared by Golder Associates Limited. 49 pp. + 2 app.

Haas, G.R. 2001. An at-risk assessment of dolly varden through a field study comparison of habitat and maximum temperature preferences with bull trout. Pp. 23-25 in Bull Trout II Conference Proceedings (Brewin, M.K. and M. Monita, eds.). c/o Trout Unlimited Canada, Calgary, AB.

Haas, G.R., and J.D. McPhail. 2001. The post-Wisconsinan glacial biogeography of bull trout (*Salvelinus confluentus*): A multivariate morphometric approach for conservation biology and management. Canadian Journal of Fisheries and Aquatic Sciences 58:2189-2203.

Haas, G.R., and J.D. McPhail. 1991. Systematics and distributions of dolly varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) in North America. Canadian Journal of Fisheries and Aquatic Sciences. 48:2191-2211.

Haas, G.R., J.D. McPhail, and A.G.N. Haas. 2001. Errors in and problems with species identification of bull trout and dolly varden. Pp. 75-76 in Bull Trout II Conference Proceedings (Brewin, M.K. and M. Monita, eds.). c/o Trout Unlimited Canada, Calgary, AB.

Hagen, J. and E.B. Taylor. 2001. Resource partitioning as a factor limiting gene flow in hybridizing populations of dolly varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*). Canadian Journal of Fisheries and Aquatic Sciences. 58:2037-2047.

Hansen, B. and J. DosSantos. 1997. Distribution of bull trout populations on the Flathead Indian Reservation, western Montana, USA. Pp. 249-254 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Henderson, N.E., and R.E. Peter. 1969. Distribution of fishes in southern Alberta. Journal of the Fisheries Research Board of Canada. 26: 325-338

Herman, S.J. 1988. An evaluation of the 1987 Pinto Lake bull trout spawning run with a comparison to 1982 and 1985. Fisheries Management Branch, Fish and Wildlife Division; Forestry, Lands and Wildlife, Rocky Mountain House, AB. 32 pp.

Herman, S.J. 1997. The unique bull trout spawning population of Pinto Lake, Alberta. Pp. 217-226 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Howell, P.J. and B. Rieman. 1997. Conservation of bull trout: theory and applications. Friends of the Bull Trout Conference Proceedings Pg. 448 in (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Hunt, C.W., R. Hawryluk, and D. Hildebrandt. 1997. Bull trout status in Fish Management Area Four, Alberta. Pp. 171-186 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Hvenegaard, P.J. and T.M. Thera. 2001. Monitoring the bull trout (*Salvelinus confluentus*) spawning run in Lynx Creek, a tributary to the Kakwa River, west central Alberta. Pp.147-151 in Bull Trout II Conference Proceedings (Brewin, M.K. and M. Monita, eds.). c/o Trout Unlimited Canada, Calgary, AB.

Hvenegaard, P. and D. Fairless. 1998. Biology and status of bull trout (*Salvelinus confluentus*) in the Kakwa River drainage, Alberta. A Fisheries Management Enhancement Project, Alberta Conservation Association. Data summary 1995 to 1997 Progress Report. Alberta Conservation Association, Northwest Boreal Region, Peace River, AB. 30 pp.

James, P.W. and H.M. Sexauer. 1997. Spawning behavior, spawning habitat and alternative mating strategies in an adfluvial population of bull trout. Pp. 325-330 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Kanda, N., R.F. Leary and F.W. Allendorf. 1997. Population genetic structure of bull trout in the Upper Flathead River drainage. Pp. 299-308 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Leary, R.F. and F.W. Allendorf. 1997. Genetic confirmation of sympatric bull trout and dolly varden in western Washington. Transactions of the American Fisheries Society. 126: 715-720.

Lohr, S., S. Duke, T. Cummings, and W. Fredenberg. 2001. Listing of bull trout as a threatened species in the United States and initial steps in the recovery planning. Pp. 199-205 in Bull Trout II Conference Proceedings (Brewin, M.K. and M. Monita, eds.). c/o Trout Unlimited Canada, Calgary, AB.

Long, M.H. 1997. Sociological implications of bull trout management in northwest Montana: illegal harvest and game warden efforts to deter poaching. Pp. 71-74 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Maxwell, B.A. 1999. A power analysis on the monitoring of bull trout stocks using redd counts. North American Journal of Fisheries Management. 19: 860-866.

McCart, P. 1997. Bull trout in Alberta: a review. Pp. 191-208 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

McIntyre, J.D. 1998. An assessment of bull trout and lake trout interactions in Flathead Lake, Montana. To The Montana Bull Trout Restoration Team; Montana Fish, Wildlife and Parks: and Confederated Salish and Kootenai tribes. 11 pp.

McLeod, C.L. and T.B. Clayton. 1997. Use of radio telemetry to monitor movements and obtain critical habitat data for a fluvial bull trout population in the Athabasca River, Alberta. Pp. 413-420 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

McPhail, J.D., and C.B. Murray. 1979. The early life-history and ecology of dolly varden (*Salvelinus malma*) in the upper Arrow Lakes. Submitted to BC Hydro and Power Authority and Kootenay Region Fish and Wildlife. 113 pp.

Mogen, J.M. and L.R. Kaeding. 2000. Ecology of bull trout (*Salvelinus confluentus*) in the Saint Mary River Drainage: A

progress report. U.S. Fish and Wildlife Service, Bozeman, Montana. Prepared for U.S. Bureau of Reclamation, Billings, Montana.

MBTRT (Montana Bull Trout Restoration Team). 2000. Restoration plan for bull trout in the Clark Ford River basin and Kootenai River basin Montana. Montana Bull Trout Restoration Team, c/o Montana Department of Fish, Wildlife and Parks, Helena, Montana. XII + 114 pp.

MBTSG (Montana Bull Trout Scientific Group). 1998. The relationship between land management activities and habitat requirements of bull trout. Unpubl. rept. prepared for the Montana Bull Trout Restoration Team, Montana Department of Fish, Wildlife and Parks, Helena, Montana. 78 pp.

Montana Natural Heritage Program. 2001. Species of Special Concern: Watch Lists. Natural Heritage Network. URL: http://nris.state.mt.us/mtnhp/ [Revision date: 1 July 2001].

Mushens, C., and J.R. Post. 2000. Population dynamics of the Lower Kananaskis Lake bull trout: 1999 progress report. University of Calgary, Calgary, AB. Prepared for Alberta Conservation Association and TransAlta Utilities. 65 pp. + app.

Nakano, S., K.D. Fausch, T. Furukawa-Tanaka, K. Maekawa, and H. Kawanabe. 1992. Resource utilization of bull char and cutthroat trout in a mountain stream in Montana, USA. Japanese Journal of Ichthyology. 39: 211-217.

National Research Council. 1995. Science and the Endangered Species Act. National Academy Press, Washington, DC. 271 pp.

NatureServe: An online encyclopedia of life [web application]. 2001. Version 1.4 . Arlington, Virginia, USA: Association for Biodiversity Information. Available: http://www.natureserve.org/ [Accessed: 25 July 2001].

Nelson, J.S. and M.J. Paetz. 1992. The Fishes of Alberta, second edition. The University of Alberta Press and the University of Calgary Press, Edmonton and Calgary, AB. 437 pp.

Olmsted, W.R., D. den Biesen, and G.J. Birch. 1999. Migration timing and abundance trends in an adfluvial bull trout population in Kootenay Lake, British Columbia. Prepared by BC Hydro, Kootenay Environmental and Social Issues Department, Castlegar, BC. 16 pp.

Paul, A.J. 2000. Recruitment dynamics in bull trout (*Salvelinus confluentus*): Linking theory and data to species management. Ph. D. Thesis, University of Calgary, Calgary, AB. 251 pp.

Paul, A.J., J.R. Post, G.L. Sterling, and C. Hunt. 2000. Density-dependent inter-cohort interactions and recruitment dynamics: models and a bull trout time series. Canadian Journal of Fisheries and Aquatic Sciences. 57: 1220-1231.

Pollard, S., and T. Down. 2001. Bull trout in British Columbia – A provincial perspective on status, management and protection. Pp. 207-214 in Bull Trout II Conference Proceedings (Brewin,

M.K. and M. Monita, eds.). c/o Trout Unlimited Canada, Calgary, AB.

Post, J.R., and A.J. Paul. 2000. A quantitative assessment of the recovery of bull trout populations in Alberta and development of models of sustainable yield. University of Calgary, Calgary, AB. Prepared for Alberta Conservation Association. Section 6 Chapters 6 and 7, pp. 146-220.

Ramstead, S. 1997. Managing bull trout trough enforcement and education in Alberta. Pp. 75-82 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Ratcliff, D.E., S.L. Thiesfeld, W.G. Weber, A.M. Stuart, M.D. Riehle, and D.V. Buchanan. 1996. Distribution, life history, abundance, harvest, habitat, and limiting factors of bull trout in the Metolius River and Lake Billy Chinook, Oregon, 1983-1994. Fish Division, Oregon Department of Fish and Wildlife. Information Reports Number 96-97. 44 pp.

Rhude, L.A., and J. Stelfox. 1997. Status of bull trout in Alberta's Fish Management Area Three. Pp. 161-170 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Rhude, L.A. and P.J. Rhem. 1995. Bull trout population status, spawning and seasonal movement in the Upper Clearwater drainage, Alberta 1992 and 1993. Alberta Environmental Protection, Natural Resource Service, Fish and Wildlife, Rocky Mountain House, AB. 166 pp.

Reiser, D.W., E. Connor, K. Binkley, K. Lynch, and D. Paige. 1997. Evaluation of spawning habitat used by bull trout in the Cedar watershed, Washington. Pages 331-338 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Rieman, B.E. and F.W. Allendorf. In press. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management.

Rieman, B.E., and J.D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society. 124:285-296.

Rieman, B.E., and J.D. McIntyre. 1996. Spatial and temporal variability in bull trout. North American Journal of Fisheries Management. 16: 132-141.

Rieman, B.E., and D.L. Myers. 1997. Use of redd counts to detect trends in bull trout (*Salvelinus confluentus*) populations. Conservation Biology. 11(4): 1015-1018.

Rieman, B.E., D.C. Lee, and R.F. Thurow. 1997. Distribution, status, and likely future trends of bull trout within the Columbia River and Klamath River basins. North American Journal of Fisheries Management. 17: 1111-1125.

Rieman, B., and J. Clayton. 1997. Wildfire and native fish: Issues of forest health and conservation of sensitive species. Fisheries. 22: 6-15.

Sexauer, H.M. and P.W. James. 1997. Microhabitat use by juvenile bull trout in four streams located in the eastern Cascades, Washington. Pp. 361-370 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Spalding, S. 1997. The status and distribution of bull trout in the Olympic Peninsula, Washington. Pp. 255-259 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Stelfox, J.D. 1997. Seasonal movements, growth, survival and population status of the adfluvial bull trout population in lower Kananaskis Lake, Alberta. Pp. 309-316 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Sullivan, M. 2001. How much angling pressure can a bull trout population sustain? Pp. 85 in Bull Trout II Conference Proceedings (Brewin, M.K. and M. Monita, eds.). c/o Trout Unlimited Canada, Calgary, AB.

Taylor, E.B., Z. Redenbach, A.B. Costello, S.M. Pollard, and C.J. Pacas. 2001. Nested Analysis of genetic diversity in northwestern North American char, dolly varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*). Canadian Journal of Fisheries and Aquatic Sciences. 58: 406-420.

Thera, T.M., P.J. Hvenegaard, A.J. Paul and J.R. Post. 2001. Identification of research priorities for a fluvial bull trout (Salvenlinus confluentus) population using a quantitative life-cycle model in a simulation modelling framework. Pp. 105-107 in Bull Trout II Conference Proceedings (Brewin, M.K. and M. Monita, eds.). c/o Trout Unlimited Canada, Calgary, AB.

Thomas, J.E., D. Groft, L. Chew, and T. Clayton. 2001. Genetic variation in bull trout (*Salvelinus confluentus*) from Alberta and Northern Montana. Pp. 117-118 in Bull Trout II Conference Proceedings (Brewin, M.K. and M. Monita, eds.). c/o Trout Unlimited Canada, Calgary, AB.

Thurow, R.F. 1997. Habitat utilization and diel behaviour of juvenile bull trout (*Salvelinus confluentus*) at the onset of winter. Ecology of Freshwater Fishes. 6:1-7.

US Fish and Wildlife Service. 2001. Species Information: Threatened and Endangered Animals and Plants. Washington D.C. 20240. URL: http://endangered.fws.gov/ [Revision date: 9 July 2001].

Van Tighem, K. 1997. My grandfather's trout. Pp. 83-88 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Walty, D.T. and D.R. Smith. 1997. Incorporating local knowledge into bull trout management in northwestern Alberta. Pp. 187-190 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Watson, G., and T.W. Hillman. 1997. Factors affecting the distribution and abundance of bull trout: An investigation at hierarchical scales. North American Journal of Fisheries Management. 17: 237-252.

Westover, W.T. 1999. Wigwam River bull trout (creel survey) – Habitat Conservation Trust Fund Progress Report (1998). Fisheries Project Report KO 55. 8 pp. + 3 apps.

Williams, R.N., R.P. Evans and D.K. Shiozawa. 1997. Mitochondrial DNA diversity patterns of bull trout in the upper Columbia River basin. Pp. 283-298 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

APPENDIX 1. Glossary of Terms

Adfluvial - Adfluvial fish populations spawn and rear in tributary streams but adults reside downstream in lakes or reservoirs.

Anadromous - Anadromous fish populations spawn and rear in freshwater streams but adults reside in the ocean.

Creel - A container used to carry fish that have been kept by anglers. A creel census or survey is a record of the fish caught by anglers (Nelson and Paetz 1992).

Diel - Diel behaviour indicates the distinct types of behaviour that occur throughout the 24 period of one day.

Entrainment - Entrainment is the process by which fish are pulled through a water diversion device and trapped in water bodies such as irrigation canals.

Extirpated - 0 bull trout/km or 0% of sportfish population

Fecundity - The number of eggs in the ovaries that are mature or will mature (Nelson and Paetz 1992).

Fluvial - Fluvial fish populations spawn and rear in tributary streams but adults reside downstream in mainstem rivers.

Incidental - 1 bull trout/km or 1% of sportfish population.

Littoral - The littoral zone of a lake is the zone around the perimeter of the lake that supports the growth of aquatic vegetation.

Metapopulation - A metapopulation is multiple sub-populations connected by intermittent immigration and emigration.

Pelagic - The pelagic zone of a lake is the open water zone of the water column away from the bottom.

Precocious - Precocious or satellite males are male fish that are generally smaller in size and reach sexual maturity at an earlier age than the average male in the population. Because of their size, these males are unable to compete with the larger males for mates. Instead, these males achieve reproductive success by sneaking into redds while other fish are spawning and fertilizing some of the eggs.

Profundal - The profundal zone of a lake is the bottom part of the water column in the part of the lake where there is too little light to support plant growth.

Redd - The gravel nest of salmonids. The eggs are deposited in the redd and remain there until they hatch (Nelson and Paetz 1992).

Resident - Stream resident fish populations reside in the tributary streams where they spawn and rear, with no adult migration to other water systems.

Remnant - 1-10 bull trout/km or 1-10% of sportfish population.

Self-Sustaining - ≥10 bull trout/km or >10% of sportfish population.

Sneaking/Satellite Male - See precocious.

Sympatry - two species living in the same geographic area.

APPENDIX 2. Definitions of selected legal and protective designations.

A. Status of Alberta Wild Species 2000 (after Fish and Wildlife Service 2001)

2000 Rank	1996 Rank	Definitions
At Risk	Red	Any species known to be at risk after formal assessment and designation as Endangered in Alberta or in Canada (in the part of the range that includes Alberta).
May Be At Risk	Blue	Any species believed to be at risk. These species will require a detailed assessment for possible formal designation as Endangered or Vulnerable.
Sensitive	Yellow	Any species known to be, or believed to be, particularly sensitive to human activities or natural events.
Secure	Green	Any species known to be, or believed to be, not at risk.
Undetermined	Status Undetermined	Any species where not enough information exists to adequately use the ranking system (exceptional cases only).
Not Assessed	n/a	Any species known or believed to be present but which have not yet been evaluated.
Exotic/Alien	n/a	Any species that have been introduced as a result of human activity.
Extirpated/Extinct	n/a	Any species no longer thought to be present in the jurisdiction or are believed to be extinct.
Accidental/Vagrant	n/a	Any species occurring infrequently and unpredictably outside their usual range.

B. Alberta Wildlife Act

Species designated as 'endangered' under the Alberta Wildlife Act include those defined as 'endangered' or 'threatened' by *A Policy for the Management of Threatened Wildlife in Alberta* (Alberta Fish and Wildlife 1985):

Endangered	A species whose present existence in Alberta is in danger of extinction within the next decade.
Threatened	A species that is likely to become endangered if the factors causing its vulnerability are not reversed.

C. United States Endangered Species Act (after National Research Council 1995)

Endangered	Any species which is in danger of extinction throughout all or a significant portion of its range.
Threatened	Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

D. Committee on the Status of Endangered Wildlife in Canada (after COSEWIC 2001)

Extinct	A wildlife species that no longer exists.
Extirpated	A wildlife species that no longer exists in the wild in Canada, but exists elsewhere in the wild.
Endangered	A wildlife species that is facing imminent extirpation or extinction.
Threatened	A wildlife species that is likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern (Vulnerable)	A wildlife species of special concern because it is particularly sensitive to human activities or natural events, but does not include an extirpated, endangered or threatened species.
Not at Risk	A wildlife species that has been evaluated and found to be not at risk.
Indeterminate	A species for which there is insufficient scientific information to support status designations.

E. Heritage Status Ranks: Global (G), National (N), Sub-National (S) (after Nature Serve 2001)

G1/N1/ S1	**Critically Imperiled**: Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).
G2/N2/ S2	**Imperiled**: Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).
G3/N3/ S3	**Vulnerable**: Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
G4/N4/ S4	**Apparently Secure**: Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.
G5/N5/ S5	**Secure**: Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals.
GX/NX/ SX	**Presumed Extirpated**—Element is believed to be extirpated from the nation or subnation*. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
GH/NH/ SH	**Possibly Extirpated** (Historical)—Element occurred historically in the nation or subnation*, and there is some expectation that it may be rediscovered. Its presence may not have been verified in the past 20 years. An element would become NH or SH without such a 20-year delay if the only known occurrences in a nation or subnation were destroyed or if it had been extensively and unsuccessfully looked for. Upon verification of an extant occurrence, NH or SH-ranked elements would typically receive an N1 or S1 rank. The NH or SH rank should be reserved for elements for which some effort has been made to relocate occurrences, rather than simply using this rank for all elements not known from verified extant occurrences.

APPENDIX 3. The current and historical distribution and abundance of bull trout in Alberta. (Information extracted from Berry 1994, Brewin 1994b, Brewin and Brewin, 1997, Donald and Stelfox 1997, Fitch 1997, Hunt et al. 1997, McCart 1997, Rhude and Stelfox 1997, Walty and Smith 1997).

Region	Historical Distribution/ Abundance	Present Distribution/ Abundance	Exotic Species Distribution
Alberta		Found in 20,000 km stream habitats and 12,000 ha of lake habitat in 24 lakes	
FMA2 (Southern Region) and Waterton Lakes National Park	-Historically occupied 1860 km of 43 streams in the St Mary, Belly, Castle, Crowsnest, and Oldman drainages. -Historically occupied 2 lakes	-Presently occupy 581 km of stream habitat - -Extirpated from Crowsnest Lake -Distribution has declined to 31% of historical range during last century, although, mostly since the 1950s (20% St. Mary, 30% Belly, 24% Waterton, 95% Castle, 18% Crowsnest, ~0% Willow, 33% Oldman) -No longer occurs in 33% of historically occupied water bodies	-Brook trout are present in all drainages except the St. Mary's drainage -Brown trout are present in the Waterton, Crowsnest, and Oldman drainages
FMA3 (Eastern Slopes Region)	Historically found in 172 streams and rivers Historically found in 11 lakes	-49% (90 waterbodies) self-sustaining -17% (32) remnant -14% (26) incidental -7% (13) extirpated -13% present with unknown status -41% of current populations are at high risk of extirpation especially in more southerly and easterly areas	In waters frequented by bull trout, 40% (70 streams and 3 lakes) contain brook trout 14 % contain brown trout
FMA4 (Eastern Slopes Region) Athabasca, North Saskatchewan, and Smoky River drainages.	Historically found in 17 lakes	-Only common in 3 lakes (18% of historical distribution -Reported in 126 streams (confirmed in 92) within the last 25 years -Only common or abundant in 40% (17/42) streams with fish catches (n≥30) -Most tributary systems have self-sustaining populations (Brazeau/ North Saskatchewan, Athabasca except Pembina, and Smoky/ Peace River system) -However, in the McLeod River system only 27% are self-sustaining, 33% in the Wildhay system and 42% in the Berland River system	Of 42 streams: 36% (19 streams) contain brook trout 7 % (3) have brown trout -Exotic Species introduced to 5 lakes -4 lakes rotenoned in 1969
FMA5 (Lower Red Deer River)		Mostly Extirpated	
FMA6 (Smoky/Peace River Region)		Self-sustaining populations more common than other areas	No exotic species (brook or brown trout)
Mountain Lakes in southern Alberta (BC) (K-country, BNP, JNP, Yoho)	Estimate from historical data - bull trout indigenous to 2% (19) of the lakes along the continental divide	Persistent in 63% (12/19) lakes although population status is unknown	Persist in 3 lakes where only *Oncorhynchus* species were introduced Extirpated from (7/9) lakes where *Salvelinus* spp. were introduced

APPENDIX 4. Land-use events and bull trout declines in southwestern Alberta. Extracted from Fitch (1997).

Drainage	Type of Habitat Disturbance (Watershed)	Date	Period of bull trout decline/ disappearance
St Mary River & tributaries	Reservoir construction (St. Mary River) Irrigation agriculture, irrigation diversion, timber harvest (Lee Creek)	1946 1950s	1960s
Belly River & tributaries	Three irrigation diversion weirs (Belly River) Reservoir construction (Waterton River) Reservoir construction (North Drywood Creek, Drywood Creek) Gas exploration, development, and processing (Drywood drainage)	1920s 1964 1960s 1950s	1960s
Castle River & tributaries	Timber harvest (West Castle, South Castle, Carbondale drainages) Road improvement (South Castle) Timber harvest, road improvement (Carbondale drainage, South and West Castle drainages) Gas exploration	1940s 1953 1960s, 1970s 1960s, 1970s	1960s – 1970s
Crowsnest River & tributaries	CPR construction Coal mine developments Timber harvest Road improvements Urban development	1897-98 1902-1970s 1902-1960s 1920s – 1970s 1902 – present	1950s – 1960s
Oldman River & tributaries	Road improvement (Forestry Trunk Road) (Upper Oldman drainage) Timber harvest (Upper Oldman drainage) Reservoir construction (Willow Creek) Irrigation diversion (Willow Creek drainage) Gas exploration (Upper Oldman, Porcupine Hills)	1953 1960s – present 1966 1960s 1960s – 1970s	1960s – 1970s

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